NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE PERFORMANCE AND COMPATIBILITY OF THIN CLIENT COMPUTING WITH FLEET OPERATIONS

by

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June 2006

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 2006	Master's Thesis

4. TITLE AND SUBTITLE: The Performance and Compatibility of Thin Client Computing with Fleet Operations	5. FUNDING NUMBERS
6. AUTHOR(S) Kenneth J. Landry	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited	

13. ABSTRACT (maximum 200 words)

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The results show that TCSBC could provide a practical and financially sound solution in meeting the Navy's need to reduce costs and propagate the latest technology to all personnel. This solution may not meet the requirements of all naval commands. A thorough performance analysis should be conducted of the applications employed and the overall expenditures prior to implementation.

14. SUBJECT TERMS Thin Client, Thin Client/Server-Based Computing, Total Cost of Ownership, Windows Based Terminals, Wyse, Expanion	15. NUMBER OF PAGES 105
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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THE PERFORMANCE AND COMPATIBILITY OF THIN CLIENT COMPUTING WITH FLEET OPERATIONS

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requirements for the degree of

MASTER OF SCIENCE IN INFORMATION SYSTEMS AND OPERATIONS

from the

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This research will explore the feasibility of replacing traditional networked desktop personal computers (PC) with a thin client/server-based computing (TCSBC) architecture. After becoming nearly extinct in the early 1990s, thin clients are emerging on the forefront of technology with numerous bandwidth improvements and cost reduction benefits.

The results show that TCSBC could provide a practical and financially sound solution in meeting the Navy's need to reduce costs and propagate the latest technology to all personnel. This solution may not meet the requirements of all naval commands. A thorough performance analysis should be conducted of the applications employed and the overall expenditures prior to implementation.

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ACKNOWLEDGMENTS

I would like to extend my thanks and appreciation to a number of people, especially my experiment volunteers, for their assistance in making this thesis a valuable learning experience.

I would like to extend a personal thanks to my primary thesis advisor Dr. Douglas Brinkley, whose enthusiasm, patience, and wisdom led to the successful completion of this paper. I would also like to thank my associate advisor Tony Kendall for his keen insight in providing fine-tuning of this thesis.

I was also fortunate to be buoyed by the support, encouragement, and pride of my Mom, my sisters, their families, as well as my doting second family that I inherited when I married my wife. Dad, I wish you were here to share this experience with me.

Finally, deep, heartfelt, and special thanks are extended to my wife Jill, son Zachary, and daughter Georgia. They have all been an exceptional support base. Georgia, thank you for your daily challenges; you really bring out the best in me. Zachary, thank you for keeping me young at heart and providing me with those daily reminders of what is really important in life. Jill, my deepest gratitude goes to you, editing every page for grammar and content, providing your love and understanding on a daily basis, sacrificing your needs to follow me around the world and providing me with a sense of purpose in my life. Without you, none of this could have been possible.

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I. INTRODUCTION

A. OVERVIEW

Computer technology and architecture in society have evolved over the past two decades from room-size mainframe computing models with “dumb terminals” to distributed networked Personal Computer (PC) models.[1] Technology advancements have also helped the U.S. Navy to downsize as fewer people are required to do the same amount of work. It is now commonplace to have a computer in every office for every supervisor. While the increased use of technology has improved the productivity of Navy commands in general, it has also greatly increased the workload upon the Information Technology (IT) staff. The IT related administration, maintenance, and security issues that have emerged are complex and will become even more complicated in the future. The literature researched for this thesis strongly indicates that a smaller IT staff can support more stations and users in a thin client server based environment than in a networked desktop PC model.

The focus of this thesis is to evaluate the performance, compatibility, and feasibility of thin client server based computing for Fleet Operations. Three different devices, the Expanion L100 terminal, the Wyse Winterm V90 terminal, and a basic laptop computer were examined throughout this thesis as alternatives to the traditional desktop PC network model.

[1] THINC: A Remote Display Architecture for Thin-Client Computing, accessed 14 Mar 2006 at URL: http://www1.cs.columbia.edu/~library/TR-repository/reports/reports-2004/cucs-027-04.pdf

Chapter II will give an overview of thin clients by describing some of the advantages, disadvantages, and other issues necessary to consider when examining thin client/server-based computing (TCSBC).

Chapter III will provide detailed specifications of the server and the thin clients used in the study. It will also include benefits of and problems within each thin client alternative investigated.

Chapters IV and V will be dedicated to detailing the experiment that was conducted and analyzing the data that was collected.

B. BENEFITS OF STUDY

As the Navy continues to depend increasingly upon technology for war fighting, so must its personnel and equipment. Fleet reduction coupled with an increase in operation tempo has brought the Navy the ongoing problem of how to quickly and efficiently deliver the most current information directly to the right people.[2]

Thin client computing fits well into all three elements of the Sea Power 21 program: the innovative process (Sea Trial), investment in people (Sea Warrior), and improved business practices (Sea Enterprise).[3]

Although thin client computing is not a new idea, it has recently become a more viable option due to rapid improvements in network bandwidth and lower costs for devices. Recent trends show the thin client market is growing. Research by the group International Data

[2] TRANSFORMING THE NAVY: Punching a Feather Bed, Accessed 13 Mar 2006, available at URL: http://www.nwc.navy.mil/press/rreview/2003/summer/art5-su3.htm

[3] Ibid, para. 15.

Corporation (IDC) predicts that it will outpace the PC market and continue to grow at nearly 20 percent per year for the next several years.[4]

As a capital investment in personnel, thin client computing has doubled the value. First, on the network management side, it has the potential to allow a smaller staff to support and maintain a thin client network equal to or greater than that of an existing desktop PC network. Secondly, as a quality of life (QOL) improvement, the most current technology will be accessible to every user on the network regardless of rate or rank. For example, this would eliminate the crew's library from having antiquated computers due to budget shortages, and it could thereby promote the Navy's already popular education-at-sea program.

The Sea Enterprise program is based on improving business practices, which can be described in lay terms as the most "bang for your buck." If implemented properly, a thin client solution can improve the efficiency and financial bottom line of any Navy command.

Innovation, quality of life improvements, and the potential cost saving benefits of thin client computing should generate interest as a program candidate for the Chief of Naval Operations (CNO) *Sea Power 21*.

[4] Wyse Technology – Corporate Profile, Accessed 13 Mar 2006, available at URL: http://www.wyse.com/about/corporate/profile.asp

C. RESEARCH QUESTIONS

1. Primary Research Question

Is Thin Client Server Based Computing technology a viable alternative to the standard WINTEL networked PCs used in fleet applications today?

2. Secondary Research Questions

How compatible are thin clients with the software prescribed by IT21 and other applications in use today?

How does the performance of the Client/Server infrastructure used in thin client applications compare with the stand-alone computers most commonly used today?

How will the typical maintenance issues handled by an IT staff be reduced or changed by this architecture?

What commands if any could best be served by this architecture?

II. LITERATURE REVIEW

A. THIN CLIENTS THEN AND NOW

Even though most people have never heard the term "thin client" before, it is not a new concept. Thin clients were in fact part of the original concept in computing with large mainframes (see Figure 1) and client stations (see Figure 2) where workers clicked away at their keyboards. Not many computers were available in the early stages of the technology and the few that were available existed for the sole purpose of performing calculations.[5] The popularity of the desktop PC soared in the late 1980s and early 1990s, nearly erasing thin client technology from the computer revolution.

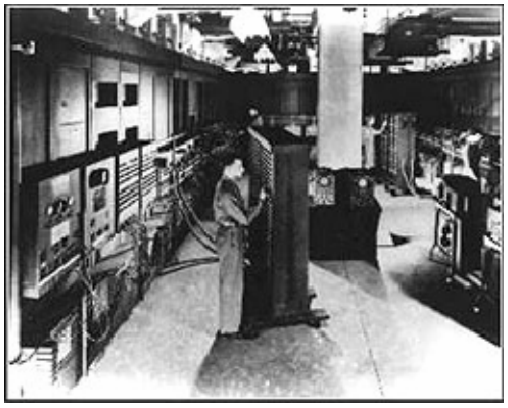

Figure 1. Early Mainframe Computers[6]

[5] What is thin client computing? Accessed 15 March 2006, available at URL: http://www.thinclient.net/hwatis_thinclient.html

[6] Ibid.

Figure 2. Early Client Stations[7]

Computer technology has come full circle with the rebirth of thin client computing. Advances in reducing the bandwidth limitations and cost of thin clients, coupled with growing security and management concerns of networked desktop PCs, have escalated interests in TCSBC as an alternative business solution. Thin client progress has been tracked for the past seven years and each year their market share has grown by nearly 20 percent.[8]

B. DEFINING THIN CLIENT/SERVER-BASED COMPUTING (TCSBC)

Over time, the meaning of thin clients has taken on many different scenarios. For the purpose of this thesis, a thin client is defined as a desktop appliance that does not contain any moving component such as a hard drive, floppy drive, or CD-ROM, and executes applications from a central server instead of a traditional desktop PC.[9]

The concept of running all user applications on a central server is considered server based computing. This

[7] What is thin client computing?

[8] Wyse Technology – Corporate profile.

[9] Increasing Control and Reducing Costs with Thin Clients. Accessed 15 March 2006, available at URL: http://www.picktrg.com/pubs/thinclient_wp062804.pdf

allows all applications to be deployed, managed, supported, and executed from a central location. This is extremely advantageous to any IT staff in contrast to the traditional desktop architecture model of managing applications on multiple PCs.[10]

C. THIN CLIENT TYPES

1. Ultra Thin Client

This version, shown in Figure 3, is the textbook example of a thin client. The user has a keyboard, mouse, and monitor, and all processes are executed by the server. The device contains no hard disk, expansion cards, disk drives, or memory cards.[11]

Figure 3. Sun Ray 170 Ultra-Thin Client[12]

2. Windows Based Terminals (WBT)

There are two types of terminals designed to complement the Windows operating system. The first type, shown in Figure 4, contains the WBT standard and utilizes Remote Desktop Protocol (RDP) or Citrix Independent

[10] Increasing Control and Reducing Costs with Thin Clients.

[11] Thin client networking. Becta technical papers. Accessed 16 March 2006, available at URL: www.becta.org.uk/subsections/foi/documents/technology_and_education_research/thinclient.pdf

[12] Sun Ray 170 Ultra-Thin Client. Accessed 16 March 2006, available at URL: http://www.sun.com/sunray/sunray170/

Computing Architecture (ICA) to display the Windows environment on the user's screen.[13]

Figure 4. Wyse S10 Thin Client[14]

The second type, as shown in Figure 5, displays Windows applications in a proprietary client operating environment with the use of ICA. (Linux with Tarantella)[15]

Figure 5. Neoware E370 with LINUX[16]

[13] Thin client networking. Becta technical papers.

[14] Wyse Products and Services. Accessed 16 March 2006, available at URL: http://www.wyse.com/products/winterm/S10/index.asp

[15] Thin client networking. Becta technical papers.

[16] Lenovo, Neoware thin clients. Accessed 16 March 2006, available at URL: http://www.pc.ibm.com/us/newoare/index.html

3. Blade PC Architecture

This is an emerging technology that utilizes PCs as individual servers. The PCs are maintained in a central location where a "manager server" performs load balancing between them. This technology is sometimes referred to as a high-density server and is typically used for the purpose of clustering.[17]

4. Tubby Clients

These are typically seen in schools attempting to extend the useful life of old computers for the benefit of the students. These clients are PCs that generally have their own operating system and they either run applications locally or connect to a server via thin client software. This may be necessary to run applications that are too rigorous for the PC to handle locally or have licensing restrictions.[18]

D. THIN CLIENT ADVANTAGES

1. Lower Total Cost of Ownership

The main advantage of thin client computing noted by most experts is a reduction in Total Cost of Ownership (TCO). TCO is an analysis model, introduced in 1987 by the Gartner Group, employed to explain the costs of purchasing and maintaining a computing environment.[19] The purchase price of the computers themselves is only a small part of TCO. Other costs include repairing computer hardware, installing and updating software, network downtime, and powering the computing infrastructure. As this list shows,

[17] Thin client networking. Becta Technical papers.

[18] Ibid.

[19] Technologies for Thin Client Architectures. Accessed 15 March 2006, available at URL: http://www.ifi.unizh.ch/ifiadmin/staff/rofrei/DA/DA_Arbeiten_2002/Stock_Mike.pdf

TCO represents the direct costs (DC) and indirect costs (IDC) of maintaining a computer network, and Figure 6 shows the percentage of each category.

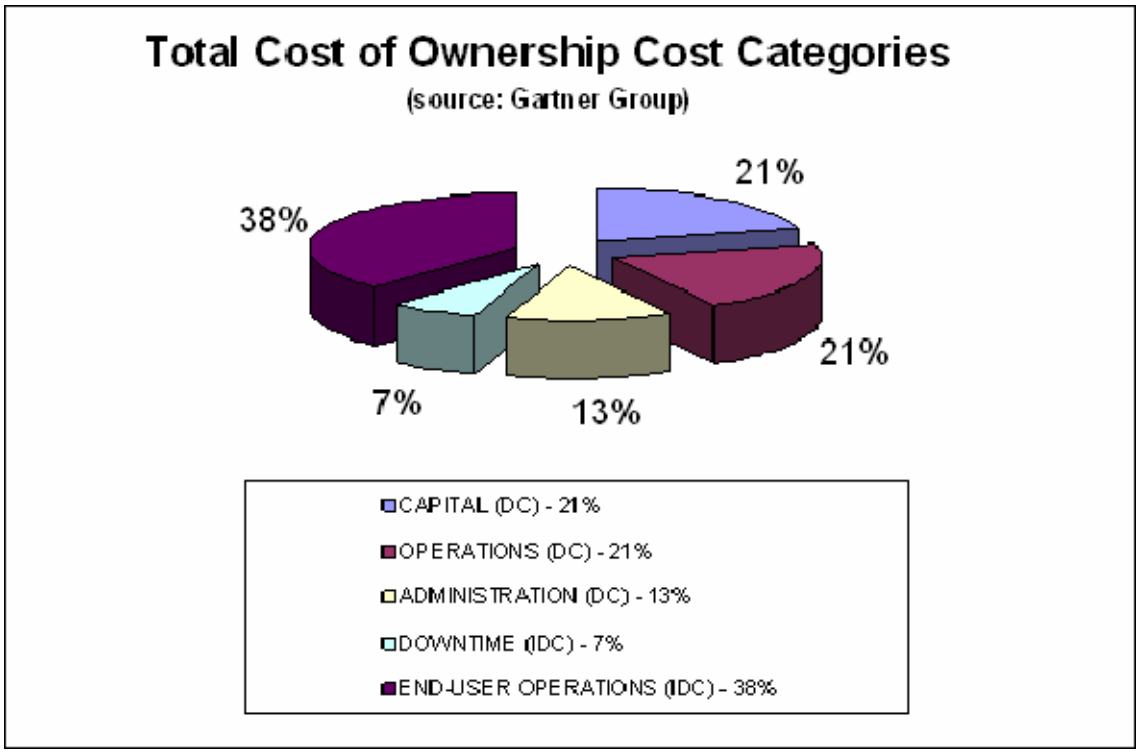

Figure 6. TCO Breakdown

Direct costs refer to items that can be easily calculated and budgeted for such as network hardware, software licenses, power savings, and telecommunication requirements.[20]

Indirect costs are associated with non-tangible items such as productivity loss due to training, downtime, or time spent on end user support.[21]

Studies have shown that the initial cost benefit of thin clients over desktop PCs has been small, if any, but

[20] Increasing Control and Reducing Costs with Thin Clients.

[21] Ibid.

over a period of time the cost savings can be significant. A report prepared by Zona Research that compared the set-up and maintenance cost of fifteen thin clients in contrast to fifteen PCs calculated a 54-57 percent savings over a five-year period.[22]

In 2004, the Gartner Group performed a per user TCO Comparison evaluation of alternatives to the existing baseline PC within the Army. The results in Table 1 show that there would be approximately a 20 percent savings per user.

Per User Army Wide (78,488 user base)	Baseline	Thin Client
Direct Costs (Hardware, Software, Operations, and Administration)	$3,095	$3,717
WAN/MAN Direct Costs (Hardware, Software, Personnel, Transmission)	$555	$1,219
Indirect Cost (End User Ops. & Downtime)	$6,424	$3,115
Total Cost per user	$10,075	$8,052

Table 1. Army Per User TCO Comparison[23]

There are several models that have shown similar results to the examples above. The figures for most models range between 20 and 35 percent savings; however, analysts caution decision makers that this data depends on many factors. Careful analysis of the individual or specific network should be performed to decide if a thin client solution is the most advantageous.[24]

[22] Understanding Thin-Client/Server Computing. Kanter, Joel, ISBN 1-57231-744-2. Accessed 16 March 2006, available at URL: http://members.tripod.com/~peacecraft/infomining/thinclnt.pdf

[23] Gartner Corporation, "Overview of Army-wide Analysis of Alternatives/Business Case analysis (AoA/BCA)," Version 7.19, 28 October 2004.

[24] Thin client networking. Becta technical papers.

2. Central Management

Implementation of central support and management of a computer network can ease the burden of an IT staff. Due to the Navy's continual downsizing and the resulting increase in IT burdens, it is important to consider that a smaller staff will have the capability to support more users.

a. Efficient Manageability

In a thin client network, only the servers require software updates. This simplifies the process and in turn gives all users instant access to the same software version.[25] This relieves the IT staff of the tedious process of visiting each individual PC to ensure they all have the most current software versions.

b. More Effective Administrator Control

Administrator's permission is required to modify configuration settings or to load software onto the system. This is paramount in preventing unauthorized use of software or the appearance of unlicensed software on the network.[26]

c. Increased Security

In a desktop PC environment, protection from the proliferation of viruses through unauthorized software and downloads has become increasingly difficult. This wastes valuable IT resources eradicating viruses and resolving the resulting system conflicts. With central management of application servers, the security updates and monitoring of

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[25] Server Based Thin-Client Computing. Amir Technology Labs. Accessed 16 March 2006, available at URL: http://whitepapers.techrepublic.com.com/whitepaper.aspx

[26] Thin client networking. Becta technical papers.

the system for unauthorized software can be more efficiently and thoroughly maintained.

d. Easier Planning

Capacity planning for budget forecasting is an easier process in a thin client environment. All processing and data storage is done centrally making it easier for managers to measure current activity and plan for future user increases.[27]

3. Server Backup

Depending on the size of an infrastructure, it is virtually impossible to back up each individual hard drive every single day. According to experts, system backup combined with client administration and support accounts for approximately two-thirds of total cost of ownership. In a thin client environment, only the server requires backup, because all applications and data are stored centrally on the server. This eliminates costs such as time and storage capabilities, and redundancies normally associated with backups in a PC environment.[28]

4. Power Savings

Power savings have become a huge issue, especially in states such as California that have continually rising energy costs. Several studies measuring the power consumption of computing devices have had varying results, but have shown consistently that thin clients consume less power than PCs. Table 2 shows the average power of three Wyse Winterm Thin Clients that are now discontinued.

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[27] Fat or Thin? Is the Verdict In? Banbury, John and Brown, Ian. Accessed 16 March 2006, available at URL: http://www.vala.org.au/vala2000/2000pdf/Ban_Bro.pdf

[28] Ibid.

	3200	3630	8230
Plugged In	5 watts	8.27 watts	6.6 watts
Powered On	6.7	26.4	7.6
Running applications from ICA session	7.07	24.07	8
Logged out	7	23.8	8
Powered Down device	5.8	9.6	7.7

Table 2. Average Power Usage[29]

Figure 7 displays a comparison of power consumption in terms of watts showing that some thin clients consume up to 85 percent less than a typical PC.

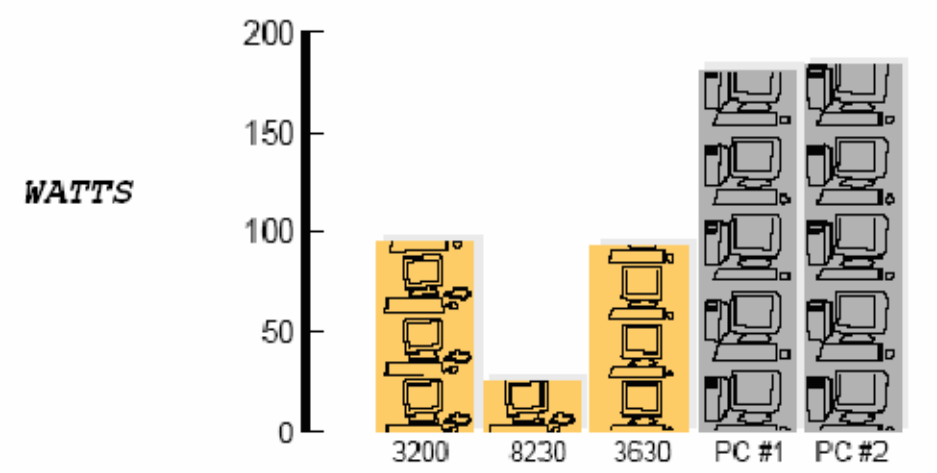

Figure 7. Power Usage Comparison[30]

The equation in Figure 8 will convert Table 2 and Figure 7 into dollar amounts and illustrates the financial savings.

[29] Desktop Energy Consumption; A Comparison of Thin Clients and PCs. Greenburg, Anderson, Sep 2001. Accessed 16 March 2006, available at URL: http://www.wyse.com/resources/whitepapers/energy.asp

[30] Ibid.

n*p*h*52 = the number of kWh your client computers use each year where:

n = number of desktop devices
p = power (in kilowatts) used by each device
h = number of hours each week that the devices are turned on
52 = number of weeks in a year

Figure 8. Yearly Power Consumption Equation[31]

For example, a typical PC uses 170 watts and it will be compared to the Wyse V90 which uses 17 watts. In a 1,000-user PC environment operated for 60 hours a week at .30 per kilowatt hour, the cost will be $159,120 (1000*.17*60*52*.30). With the Wyse V90 the cost will be $15,912 (1000*.017*60*52*.30). The savings of $143,208 is a significant reason to consider thin clients as a legitimate option.

E. THIN CLIENT CONCERNS

1. Networked PC Servers

In a PC environment, the server does not have to be as robust as thin client servers. An IT manager must also factor in the near constant attention required by thin client servers because **all** applications are executed at the server. Depending on the size of the architecture, there is a distinct possibility that multiple and very robust servers will be required to support any network. Over configuration of thin client servers is the normal mode – not an anomaly. The rule of thumb tends to be the vendor's published requirements at least doubled.[32]

[31] Desktop Energy Consumption; A Comparison of Thin Clients and PCs. Greenburg, Anderson. Sep 2001.

[32] Fat or Thin? Is the Verdict In? Banbury, John, and Ian Brown.

2. Multimedia Performance Deficiencies

Most manufacturers acknowledge that one of the shortfalls of thin clients is its poor performance with multimedia and graphic intensive programs. Advances in both processing and server technology have improved some of these deficiencies, but more progress needs to be made. Some products, such as the Windows Based Terminals, have some processing power on the clients, which allows them to run more multimedia rich programs.[33]

3. Server Dependency

A huge disadvantage of thin clients is that if the server fails, all terminals on the network are unusable and production is immobilized until the server is back on line. In a typical PC environment, if the server fails production is limited, not lost, and certain network features may be unavailable. There are some options and configurations — such as failover mechanisms, load balancing, and clustering — that may help to lessen the catastrophic nature of server failure in a thin environment.[34]

4. User Resistance

As is the case with any new idea some users will wrestle with the transformation. The user's inability to play their favorite music compact disc (CD), access a floppy drive, or install personal software will not be popular but in the long run it is a benefit to the IT staff.

5. Bandwidth Limitations

With thin client networks and the bulk of the processing transpiring on the server there is considerably

[33] Thin client networking. Becta Technical Papers.

[34] Ibid.

more network traffic than in a networked PC environment. When considering this technology careful consideration has to be given to the number of users utilizing a server.[35]

6. Lack of Disk Drives and Peripheral Devices

This may or may not be a problem depending on the thin client device being examined. Managers need to consider whether they really want users to have the option of connecting Universal Serial Bus (USB) equipment to their stations. There are some thin clients on the market that provide USB ports for the connection of peripheral devices.

F. CHAPTER SUMMARY

This chapter provided a background summary of thin clients as the first concept in computing through decades of technological evolution. The definition of TCSBC used throughout this research was provided along with a brief introduction of various types of thin client options that are available to an IT staff. The chapter concludes with an overview of some general advantages and concerns of thin client computing.

[35] Thin client networking. Becta technical papers.

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III. SURVEY OF THIN CLIENT TECHNOLOGIES

A. OVERVIEW

This chapter will describe the technological aspects, benefits, and problems experienced during the examination and operation of the thin client network technologies investigated during research.

B. APPLICATION SERVER SPECIFICATIONS

The application server that was used in this research was constructed in-house, not purchased from a manufacturer. The design of this server was based on three criteria:

- Minimize the cost of the server
- Ample storage for all classroom and lab applications
- Sufficient processing power to accommodate up to thirty simultaneous users

Table 3 below shows the specifications with which the server was designed.

Manufacturer	Custom in-house design
Processor	Dual AMD Opteron 244 CPUs
Memory	4GB RAM (Registered)
Storage Capacity	2 installed hard drives (80GB + 300GB)
Operating System	Windows Server 2003
Drives	CD/DVD-RW
Cost	$2,500 USD

Table 3. Thesis Application Server Specifications

C. PC EXPANION L100

The first thin client device examined was the NComputing model L100, also known as the PC Expanion L100 was one of the possible thin client solutions examined. NComputing was founded in 2003 and is a privately-held company established by Young Song, a former co-founder and executive of eMachines, Inc. (acquired by Gateway) and Klaus Maier, CEO of Hydrapark GmbH.[36] The L100 Expanion product using a concept known as UTMA (UltraThinMultiAccess) which is the verbiage used to describe all of NComputing's multi-user products. NComputing owns its own terminal server software, remote computing client related patent, and System on Chip (SoC) architecture intellectual properties. In addition, they take advantage of under-used CPU processor horse power of the most common and available multi-user operating systems (Microsoft Windows 2000, XP, Window Server 2003, and Linux).[37]

1. Product Specifications

Table 4 shows a list of the Expanion L100 device hardware and software specifications.

2. Expanion L100 System Benefits

a. Cost

Cost was a major factor in the selection of this unit for examination during this thesis. At the time of this thesis the cost of this unit was in approximately three hundred dollars, significantly cheaper than a baseline desktop PC.

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[36] Ncomputing – Innovative MultiUser Network Computing Solution Provider. Accessed 17 March 2006, available at URL: http://www.ncomputing.com/ncomputing/company/background.php

[37] Ibid.

Power	AC110V ~ AC220V 50/60 Hz, 5sV/2A
Dimension	215mm(W) X 40mm(H) X 160mm(D)
Weight	375g
Front	Windows for “Power”, “LAN’, “Ready” status
Top	Power Button
Ports	DC Power Jack, Speaker Jack, PS2 Keyboard Port, PS2 Mouse Port, Ethernet (RJ-45) Port, VGA Monitor Port.
Protocol	WoIP(Windows over IP), LoIP(Linux over IP)
Supporting OS	Windows 2000 Professional, Windows XP Home, Windows XP Professional, Windows XP Media Center, Windows 2000 Server, Windows Server 2003, Linux
Certificates	CE, FCC class B
Others	Monitor, keyboard, mouse, and speakers are not provided

Table 4. PC Expanion L100 Specifications[38]

b. Hassle-Free Maintenance

As with most thin client devices, the Expanion product has no moving parts and thus requires no hardware maintenance and only occasional software upgrades. The only part of the system that is required to be maintained and upgraded is the host PC making this solution extremely attractive to any IT staff looking to reduce its workload.

c. Energy and Space Efficient Design

The Expanion terminal draws a low five watts of power and has a very compact design (Figure 9), not much larger than a paper back book. The low power requirement equates to less heat, and on a Navy ship operating in the Persian Gulf that is a significant advantage. Those

[38] Ncomputing – Innovative MultiUser Network Computing Solution Provider.

familiar with Navy ships also know that space is a valuable commodity and the small size of the Expanion compared to a desktop PC is another benefit for shipboard use in the Navy.

Figure 9. Expanion L100[39]

d. Security

The Expanion system's lack of a storage device and thereby inherent protection from hacking, viruses, and illegal data leakage is a significant benefit to consider.

e. Portability

From the figures and specifications listed above it is easy to see that the Expanion has great transport possibilities. At just over a pound per unit a person can transport ten units with less effort than one desktop PC and because there are no moving parts to stabilize during shipping the packaging can be more compact than the shipment of a PC. Figure 10 shows a typical network setup using the Expanion device.

[39] Ncomputing – Innovative MultiUser Network Computing Solution Provider.

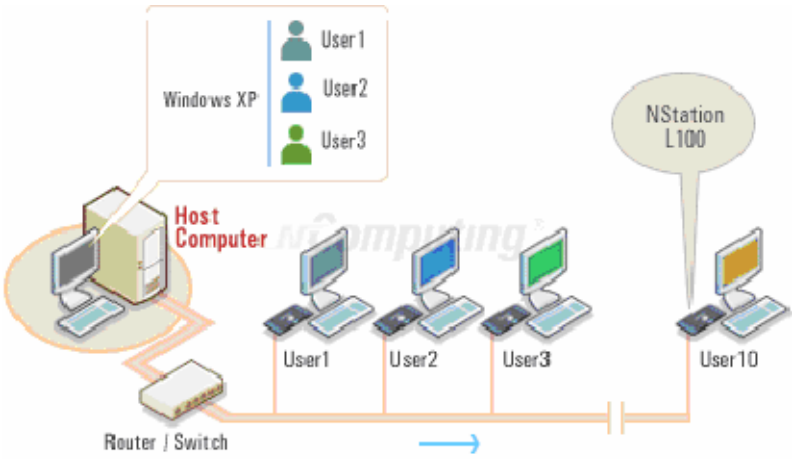

Figure 10. Typical Network Setup[40]

3. Expanion L100 Problems

a. Software Issues During Initial Setup

The initial software that came with the unit was not adequate for the initial setup. Initial setup required the user to go to a website and download the correct software. This was not a large problem during this thesis because of the controlled lab environment; however, if the initial setup were in an area of limited or no internet connectivity the system would have been completely useless. This would have also been a bigger problem if a user with little or no software experience had attempted to connect the system.

b. Inoperability with Windows Server 2003 Standard Edition

The manufacturer claims that the Expanion L100 will operate satisfactorily with the Windows Server 20003 software. This was promising since this would allow expansion of an Expanion network to thirty users instead of ten allowed by other operating systems. The initial setup was to a Windows XP professional operating system with two

[40] Ncomputing – Innovative MultiUser Network Computing Solution Provider.

Expanion boxes. All basic operational tests were satisfactory with exception of the multi-media portions. The decision was then made to connect the Expanion boxes to the server. Initially, everything seemed to work fine but then testing was degraded when the first software update for the server was installed. Immediately the Expanion boxes did not work on the server. Technical support at Expanion acknowledged the problem and stated they were working on their own software update. The Expanion software update was issued the following day, the system was updated and Expanion was operational again; however, there was a large amount of downtime, which is disastrous for any IT administration. Two server restarts and a repeat of the software issue two days later led to the disconnection of the Expanion boxes and eliminated any further consideration of those devices as a viable thin client solution.

c. Poor Multi-Media Performance

The running of 3D games and certain programs is an admitted limitation of the system by the manufacturer.[41] A very commonly used program, Windows Media Player, did not run very well at all. In fact, running Windows Media Player with only two Expanion boxes connected, the host PC had to shutdown and restarted every time.

d. No USB Ports or CD-ROM Drive Available

This was the first problem identified with this system. There is the potential solution (that was not pursued) for this problem but it would involve a great deal of effort on the part of both administrators and users. For Navy or classroom applications a USB port is of the utmost

[41] Ncomputing –Innovative MultiUser Network Computing Solution Provider.

necessity. The NComputing website did indicate that in May 2006 they expect to introduce their L200 system that includes a version 1.1 USB port.

D. WYSE WINTERM V90 AND S10

The next set of thin client devices examined came from the Wyse Corporation. According to its website, the Wyse Corporation is the global leader in thin computing. Its line of Winterm clients has led the industry each of the seven years that it has been tracked.[42] They possess forty-one of Fortune 100s companies as Wyse customers including the top three shipping companies, the top two global banks, top three government services companies, and six of the top ten hotels.[43] Wyse thin clients utilize Remote Desktop Protocol (RDP) or ICA to communicate with the host computer.

Two of the Wyse systems were purchased for comparison and testing; the S10 and the V90. The S10 was the most economical device at about the same price as the Expanion system. The V90 has more internal memory and a more sophisticated operating system; Windows XP Embedded (XPe). It is also the more expensive device costing approximately five hundred dollars for educational institutions. Both systems were easy to setup and establish connections with the server. However, the value of the improved operating system in the V90 was quickly demonstrated. The USB ports on the S10 were useless for connecting any type of USB storage device or CD-ROM because that system's operating system lacks "plug and play" functionality. The V90's XPe operating system on the other hand does offer plug and play

[42] Wyse Technology – Corporate Profile.

[43] Ibid.

recognition of flash drives and other USB storage devices. All research attention was then concentrated on the V90 system.

1. Product Specifications

Table 5 shows a list of hardware and software features for Wyse's Winterm V90 thin client device.

2. Winterm V90 System Benefits

a. Instant Setup

Upon arrival from the company, once the V90 is removed from its packaging, it is ready for connection. The V90 has no affiliated software, therefore once it has power a connection to the network is established, and its user accounts are created it is ready for RDP protocol use. When operating using the ICA protocol the network setup process could take longer but the unit setup is still the same.

b. Microsoft Windows XP Embedded Operating System (OS)

The Navy's computer infrastructure operates in a very Windows oriented environment, which makes this feature extremely attractive. The embedded OS provides fast boot up functionality and the flexibility to shift easily and rapidly from a typical desktop PC screen to the connection manager dashboard. With the embedded OS the user receives broad support for a wide range of peripherals and their drivers.[44]

[44] Wyse Technology – Global Leader in Thin Computing. Accessed 22 March 2006, available at URL: http://www.wyse.com/products/winterm/V90/index.asp

	Windows Custom-Application Terminal	- Based on Microsoft Windows XP Embedded Operating system - 512MB flash/256MB DDR RAM (standard)	- Integrated Microsoft RDP, Citrix ICA, and terminal emulation protocols standard
SOFTWARE	Firmware Features	- Microsoft Windows Xpe - Microsoft Internet Explorer 6.0 resident: HTML, Javascript, XML, Active X, Sun JRE Media Player 6.4, Citrix Web Client	- RDP 5.2 resident - Citrix ICA 8.0 resident - Terminal emulation, emulates 60 terminal types
	Protocol Support	- TCP/IP, DNS, DHCP, PXE	
	Management	- Remote management, configuration, and upgrades through Wyse Rapport client management software version 4.4.1 or later - Complete image upgrade - Wake terminal remotely (Wake-on-LAN)	- Terminal configuration (IP information, name, etc.) - Reporting - Remote screen shadowing of entire desktop (VNC) - Asset management
	Set-Up and Configuration	**User interface** - Boot from local flash	
	Server OS Compatibility/Support	- Microsoft Windows 2000/2003 Server - Microsoft Windows NT Server 4.0, Terminal Server Edition	- Citrix WinFrame and MetaFrame
HARDWARE	Processor	- True x86 CPU clocked at 1GHz	
	I/O/Peripheral Support	- Two serial ports and one parallel port - Three USB 2.0 ports - Keyboard: USB with Windows keys (104 keys) included - CardBus/PCMCIA card slot	- Mouse: PS/2 mouse included - Local printers via USB, parallel, serial, Ethernet - VGA-type video output (DB-15) - Internal smart card reader (factory installed option)
	Networking	- 10/100 Base-T Fast Ethernet, twisted pair (RJ- 45) - Wi-Fi wireless LAN connectivity via external USB	CardBus adapters (available separately)
	Audio	- Output: 1/8-inch mini, full 16-bit stereo, 48 KHz sample rate	- Input: 1/8-inch 8-bit mini microphone
	Power	- Worldwide auto-sensing 100-240 VAC, 47-63 Hz	- Average power usage: 17.2 Watts (set-up: device connected with 1 PS/2 keyboard, 1 PS/2 mouse and, monitor)
	Physical Characteristics (H x W x D)	- Height: 7.9 inches (201mm) - Width: 1.8 inches (46mm) - Depth: 7.1 inches (180mm)	- Built in Kensington security slot (cable lock sold separately) - Optional mounting bracket for wall and monitor installation sold separately - Optional vertical foot included; horizontal feet sold separately

Table 5. Wyse Winterm V90 Specifications[45]

[45] Wyse Products and Services. Accessed 18 March 2006, available at URL: http://www.wyse.com/products/winterm/V90/index.asp

c. RDP/ICA Protocol

The Wyse client gives an administrator the option of two presentation protocols, RDP or Citrix ICA. ICA offers some added features over RDP but will present additional costs due to licensing. J.D. Edwards conducted a performance comparison test of the RDP and ICA protocols and concluded that ICA outperformed RDP in all tests. However, the conclusions cautioned that the slight performance difference may not be enough to warrant the additional cost burden of the Citrix licenses.[46]

The additional features of ICA that may be beneficial to a network are:

- Support for all Windows and non-Windows clients (RDP only works with Windows)
- Supports SPX, IPX, NetBEUI, and Direct Asynch protocols in addition to TCP/IP (RDP only supports this one)
- Scalability, contains load-balancing feature, users are routed to server that offers best performance[47]

d. Cost

The V90 was not as cheap as the Expanion system, but with its additional features the V90 has more to offer a customer. The V90 thin client costs approximately five hundred dollars (S10 cost is approximately three hundred dollars). When comparing the cost of the V90 to a baseline

[46] Profile Technologies – Server based Thin Client solutions. Accessed 22 March 2006, available at URL: http://www.profiletechnh.com/TC White Papers/ICA RDP Performance.pdf

[47] Thin-client/Server Architectures. Wheeeler, Sharon. November 28, 2000. Accessed 22 March 2006, available at URL: http://www.espipd.com/ThinClients.pdf

PC, the costs are in the same range. However, the solid state design of the thin client gives it a much longer life expectancy and thus makes it much more affordable in the long run.

e. Hassle-Free Maintenance

The V90, like the Expanion, is void of any moving parts. It is a diskless, fanless, and convection cooled system. Due to the lack of moving parts, the V90 has low maintenance requirements, more durability, and less noise than a typical PC. The lack of moving parts also reduces vibration, which is important on Navy ships during certain evolutions.

f. Energy and Space Efficient Design

The V90, as seen in Figure 11, does not use up a lot of space and, with the optional monitor or wall mount kit; more desktop space will be free. The system also uses a meager 17.2 Watts when operating, compared to nearly 170 Watts for most desktop PCs.

g. Security

This is a big advantage that all thin clients have over desktop PCs. The V90 has an additional feature of a built in security slot so that it can be secured with cable lock. If stolen, the V90’s diskless box is worthless from an information standpoint because of its dependence on the server; however its small size makes it susceptible to petty theft.

h. Portability

The Wyse unit is a little heavier than the Expanion client option, however it is still much lighter than a typical desktop PC. The small size makes this unit

attractively easy to pack and distribute to remote locations for quick network setup.

Figure 11. Front and Rear View of Winterm V90[48]

3. Wyse V90 Problems

a. Multi-Media Sluggishness

From the testing performed in the lab, it is clear that the Wyse V90 exceeds the Expanion unit's capability to adequately handle multi-media tasks. However, there was a noticeable performance lag in a multi-user environment of greater than fifteen users indicating that there is still room for improvement.

b. RDP Features

This may be a problem for some administrators and users that have never used RDP, but it is one that can be overcome very easily. No documentation is included with the Wyse packaging that details how to operate the client with RDP. RDP is a Windows concept and therefore sufficient help in getting started is readily available.

E. USING A LAPTOP VIA RDP AS A THIN CLIENT

1. Product Specifications

Table 6 below displays the specifications of the laptop used for this research.

[48] Wyse – Global Leader in Thin Computing.

2. Laptop Benefits

a. Space Savings

Laptops are not as small as the thin client devices that have already been discussed, but they can be closed and placed aside to allow for more work space when necessary.

b. Portability

Using laptops as an option provides extra portability advantages over either the Wyse or Expanion. If using a laptop, the user has the ability to connect to the network server remotely via an internet connection. That type of portability creates more productive opportunities than the Wyse or Expanion units.

Model	Acer Aspire 3003 WLCI
Processor	AMD Sempron Processor 3000+
Memory	256 MB
Hard Drive	40 GB
Display	15.4″ TFT display
Multimedia Drive	DVD / CDRW combo
Operating System	Windows XP Home
Dimensions (L x W x H)	14.3″ (364mm) x 11.0″ (279mm) x 1.3″ - 1.5″ (33.9mm – 38.9mm)
Weight	6.2 lbs
External Ports	RJ-45 LAN, Three USB 2.0 ports, RJ-11 Modem
Cost	$600 USD

Table 6. Laptop Specifications

c. Network Autonomy

Like any other fat network, when using laptops as thin clients, any problem with the network does not create a complete shutdown of productivity.

3. Problems with Using a Laptop

a. Cost

The laptop purchased for this thesis cost six hundred dollars. This was a very basic laptop that has limited capabilities and probably would not be sufficient if it were to be used as travel device.

b. Maintenance Required

This is a problem especially when looking at the total cost of ownership model. The laptop's moving parts and at a minimum the operating system requires software updates. So in addition to the initial cost of the laptop, a budget has to take into account the additional maintenance and support required for upkeep.

c. Network Security Hazards

Thin clients provide safety to a network because the administrator controls access to the server and all software installed on the network. With the laptop solution users will have the potential to introduce viruses and malicious software into the network creating additional problems for administrators.

F. CHAPTER SUMMARY

This chapter presented the reader with background information and specifications for the server and thin client options examined during the course of this research. Additionally, it reveals a variety of benefits and problems experienced during setup and testing.

IV. EXPERIMENT

A. PURPOSE OF CONDUCTING EXPERIMENT

The experiment for this thesis was developed to address three main objectives:

- Test server capability
- Evaluate application performance
- Gather objective user opinions

After the initial investigation, experimentation, and research of the three thin client devices available to this project, the Wyse Winterm V90 was selected for project testing. Funding limitations prohibited the purchase of twenty to thirty Winterm devices. Because the V90 uses RDP to communicate with the server it was feasible to use one of the school's desktop PC resource labs to simulate a thin client lab using RDP.

This chapter will discuss the preparations that were performed to achieve a successful experiment, as well as an incremental accounting of the execution of the experiment. Success was defined as a user having enough data points to give an objective opinion on the server's performance for the various applications tested.

B. PREPARATIONS FOR EXPERIMENT

1. Server Software Load

a. Operating System

Microsoft's Server 2003 Standard Edition was the operating system that was loaded onto the server and used throughout the experiment. Windows Terminal Server is

included in the Server 2003 operating system and that provided the RDP interface for the thin client network.

b. Testing Applications

The applications that were utilized during the experiment were a compilation of NPS resource lab software and the Navy Air Pacific Command (COMNAVAIRPAC) Navy and Marine Corp Intranet (NMCI) Gold Disk contents. Table 7 below contains a list of the loaded applications that were evaluated during the experiment; it is not a complete list of the applications on the server.

APPLICATION	NPS	GOLD DISK	NIETHER
Adobe Acrobat			
Microsoft Word			
Microsoft Excel			
Microsoft PowerPoint			
Microsoft Access			
Microsoft Visio			
Microsoft Frontpage			
Microsoft Project			
Microsoft Publisher			
Macromedia Dreamweaver			
WinZip			
Internet Explorer			
Mozilla Firefox &			
Quick Time			
Shockwave/Flash			
Real Player			
Windows Media Player			
MiniTab			
MathType			
Navfit 98A *			

Table 7. Experiment Applications

& - Mozilla Firefox is a popular Internet browser alternative to Microsoft's Internet Explorer.

* - Navfit 98A is a fitness report program used at all Navy commands that runs in Microsoft Access.

2. Experiment Volunteers

Volunteers for the experiment were solicited via the NPS email system. A list of approximately twenty NPS students, faculty, and staff was compiled in an attempt to achieve the broadest spectrum of users and observations. Volunteers were chosen from various military branches, countries, and NPS curriculums.

Once the collection of volunteers was established, the computer lab in Ingersoll 250 was reserved for Thursday, March 9, 2006, from 1100-1500. Volunteers were requested to arrive at the lab by 1215 for a 1230 start time.

User accounts were established on the server for each volunteer. The accounts were established with a generic login name of “Expuser10 – Expuser35”, and a generic password of “Password10 – Password35”. For example, the login of “Expuser10” had a password of “Password10”. A slip of paper with the required login and corresponding password was established and placed at each computer station.

3. Institutional Review Board (IRB) Submission

This experiment entailed the participation of human subjects which required an IRB application to be submitted to the NPS IRB Committee. The submission of this package is governed by NPGSINST 3900.4 which is based on the Federal regulation 45 CFR 46. The approved package submitted for this experiment is in Appendix A.

4. Questionnaire / Survey

For this experiment, the questionnaire in Appendix B was designed to capture each participant’s unbiased opinions and observations of their experience using thin client-server/based computing architecture. The questions

were intended to have the user compare their usual desktop experiences with what they encountered during the experiment.

5. Experiment Day Lab Preparations

On the day of the experiment the server was relocated to the computer lab. A laptop running Etherpeek software was checked out from the NPS Network Operations Center (NOC) and connected to the server with a hub. The Etherpeek software provided a means of measuring packet traffic to and from the server during the experiment. Waivers, surveys, and login slips were printed out and placed at each workstation.

C. EXPERIMENT EXECUTION

1. Introduction

The experiment began with the introduction of Dr. Douglas Brinkley, thesis advisor, and Kenny Landry, experiment officiator. All candidates were asked to read and sign the waiver form. Once all the forms were signed, a brief introduction about the experiment was given. A key point stressed was the importance that once logged onto the server the user could not log off and then back on due to licensing restrictions. If there were any issues the officiator was to be notified immediately in order to rectify the situation.

2. Logging on to the Server

All users were asked to log into the computer initially using their own personal account. Once that was accomplished, everyone was instructed to start the remote desktop connection using the method in Figure 12.

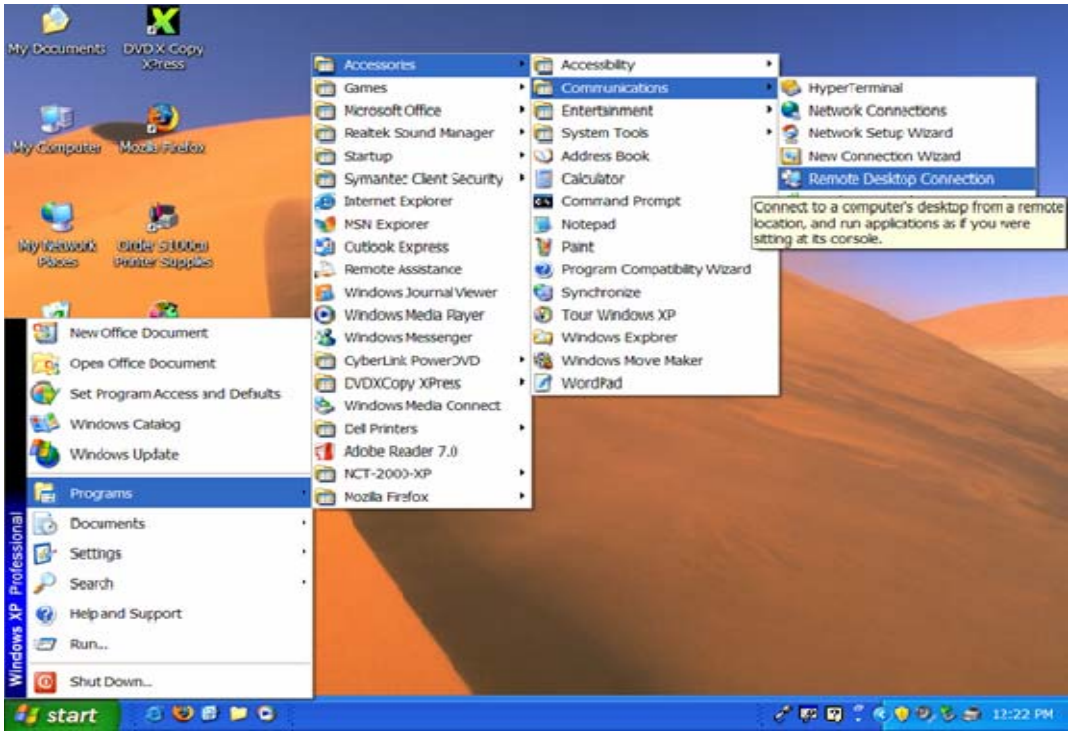

Figure 12. Initiating RDP Session

Once all computers were initialized the next step was to have the users log on to the experiment server. Users were instructed to enter the IP address for the server that was written on the classroom board as seen in Figure 13.

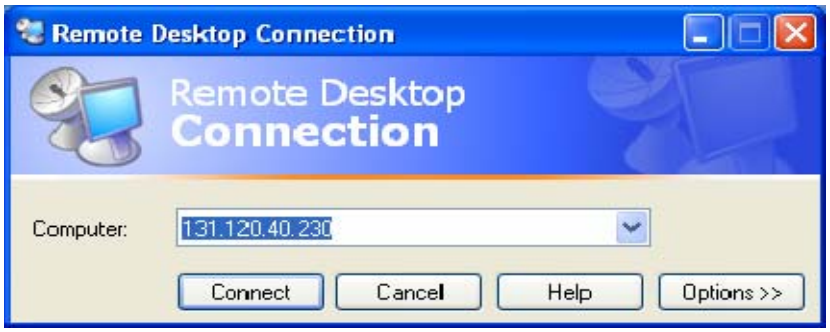

Figure 13. Server Login Screen

Once the IP address was entered the users were directed to click on the “Options” tab as seen in Figure 14.

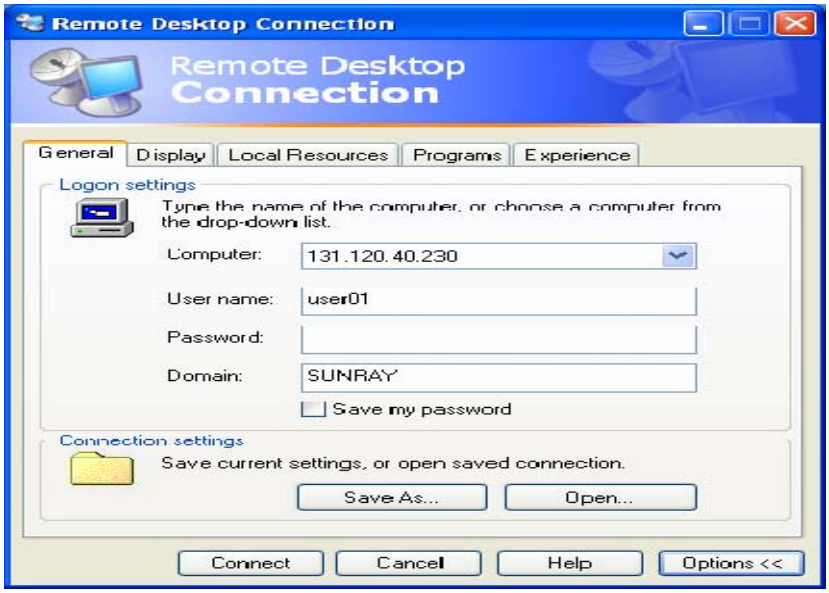

Figure 14. Expanded View of Options Tab

Users were directed to make changes to the default settings under the “Local Resources” tab, as seen in Figure 15, and the “Experience” tab as seen in Figure 16. In the “Local Resources” tab the user were asked to click on disk drives to enable the use of thumb drives as the default setting is blank.

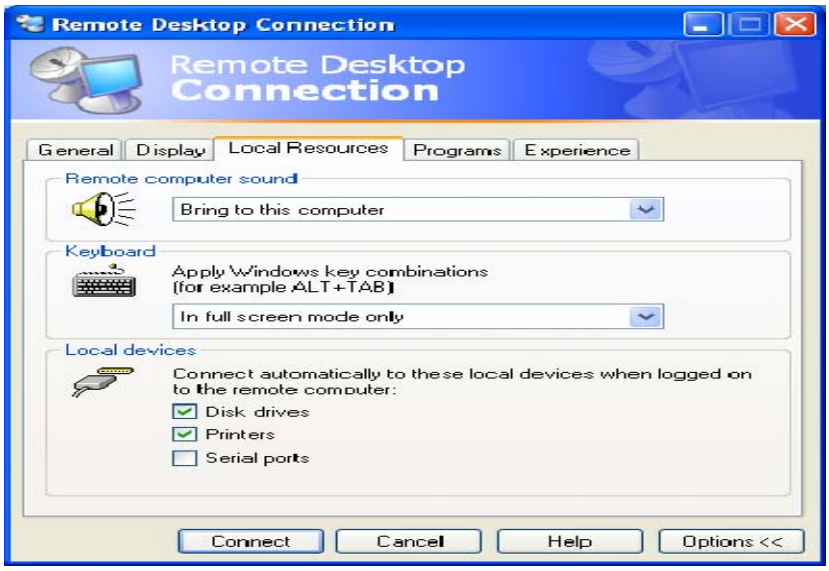

Figure 15. Local Resources Tab

In the “Experience” tab, the users were asked to access the drop down menu and select the speed of the experiment’s system “LAN (10Mbps or higher)” as the default setting is “Modem (56Kbps)”.

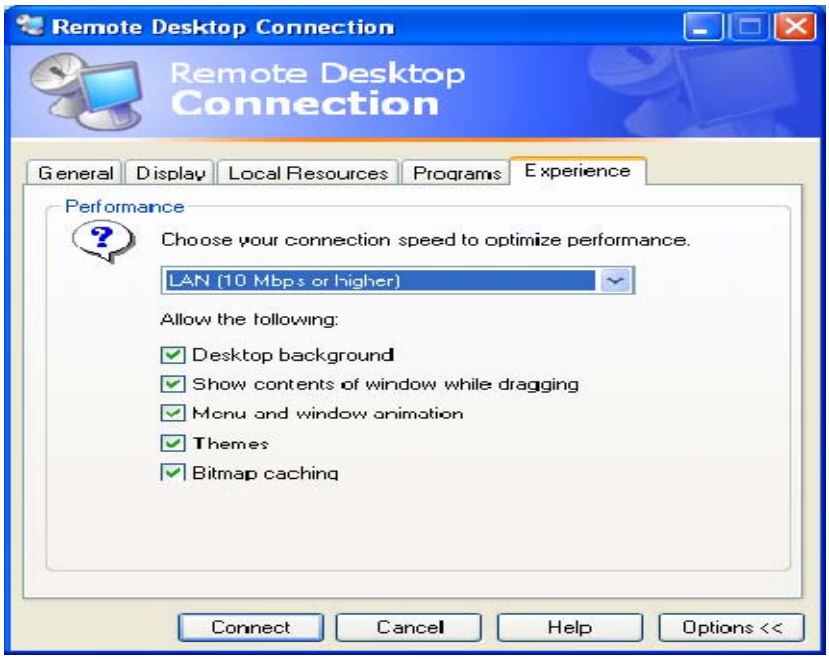

Figure 16. Experience Tab

Upon completion of changes by all users, they were then instructed to click on the “Connect” button which enabled every participant to view the default server desktop at their station.

3. Server/Application Evaluation

Once all users had gained access to the server they were asked to refrain from connecting to the internet until directed. This permitted data gathering with solely the server applications in use. Candidates were given approximately twenty minutes to navigate the server and evaluate the list of applications in the survey. The next phase involved 50 percent of the evaluation group accessing the internet while the other 50 percent continued to

evaluate the server applications to allow for another data point. Approximately ten minutes later the remaining users joined the control group and accessed the Internet. When all participants were simultaneously accessing the Internet the final data point was taken.

4. Questionnaire / Survey Completion

At 1415, approximately fifteen minutes after everyone was accessing the Internet simultaneously, the candidates were instructed to complete their individual surveys. Each survey stressed that individuals communicate objective opinions about their experience with the thin clients and provide both positive and negative feedback regarding this technology.

D. SUMMARY

The purpose of this chapter was to explain the parameters that the moderator set forth when creating this applications-based experiment. Additionally, it discussed server preparations, volunteer pool selection, and experiment day events. Finally, it offered a detailed account of the experiment execution and goal of the participant’s surveys.

V. EXPERIMENT RESULTS AND CONCLUSIONS

A. SURVEY / QUESTIONNAIRE RESULTS

The survey / questionnaire completed by experiment volunteers contained fourteen questions. These questions have been further grouped into five different categories: user demographics, general thin client observations, application evaluation, scenario evaluation, and user feedback.

1. User Demographics

Questions 1-4 were designed to obtain general background information for the experiment group.

1.) If you are military, what is your branch of service? If you are faculty, please skip to Question 4? (Question 1)

- Of the 16 volunteers, 11 were affiliated with the military. Four volunteers were NPS faculty members and one volunteer was a NPS staff member.
- Of the 11 military members, eight were affiliated with the United States Navy (USN), one was with the United States Air Force (USAF), and two were with the Polish Army.

2.) What is your warfare area (i.e. SWO, SC, IP, Infantry, Special Forces)? (Question 2)

- The USN was represented by five Surface Warfare Officers, one Submariner, one Engineering Duty Officer, and one officer from Special Forces. The USAF volunteer serves with the Military Police.

The Polish Army representatives were part of the Army Aviation and Artillery communities.

3.) What is your curriculum? (Question 3)

- Two participants were students of Special Operations (699).
- Two participants were students of Operations Analysis (360).
- Two participants were students of Information Systems and Operations (356).
- Two participants were students of Resource Planning and Management for International Defense (820).
- One participant was a student of Naval/Mechanical Engineering (570).
- One participant was a student of Manpower Systems Analysis (847).
- One participant was a student of Information Systems and Technology (370).

4.) If you are faculty or staff at NPS what department are you in? (Question 4)

- 2 of the 4 NPS faculty members were affiliated with the Naval War College; one was a member of the Defense Analysis Department; and one was a member of the Information Sciences Department. The lone NPS staff member belonged to the Graduate School of Business and Public Policy (GSBPP).

2. General Thin Client Observations

Questions 5, 7, 9, 10, and 12 pertained to the volunteer's opinion about certain aspects of their thin client experience.

1.) How complicated was the log-in procedure compared with a normal PC? (Question 5)

- 12 of 16 users considered the log-in procedure "More complicated".
- 2 of 16 users thought that the log-in was "Equal" when compared to that of a normal PC.
- 2 of 16 users did not respond.
- No user marked that logging in was "Much more complicated", "Easier", or "Much easier".

2.) How much experience have you had using thin client computers in the past? (Question 7)

- 1 of 16 users had "Significant experience".
- 3 of 16 users had "Some experience".
- 4 of 16 users were at a "Once or twice" experience level.
- 3 of 16 users "Only knew they existed".
- 5 of 16 users reported that "This is the first I have heard of them".

3.) Did you find the thin client desktop to be difficult or confusing? (Question 9)

- This was a "Yes" or "No" answer and 16 of 16 users answered "No".

4.) In your opinion, is it reasonable to use thin clients in the classroom vice standalone PCs? (Question 10)

- This was a “Yes” or “No” question and 15 of 16 users answered “Yes”.
- One user reported that he or she did not have enough information to provide a Yes or No answer.

5.) How likely are you to recommend thin clients vice standalone PCs in your work environment? (Question 12)

- 4 of 16 users answered that they “Definitely will recommend”.
- 8 of 16 users answered that they “Probably will recommend”.
- 4 of 16 users answered that they were “Not sure”.
- No user chose the options of “Probably will not recommend” or “definitely will not recommend”.

3. Application Evaluation

Question 6 was designed to gather a user’s overall observations of experiment applications. Users were given six choices in rating each application’s performance. Table 8 will display the tally of all users.

APPLICATION	Definitely Better	Better	Equal	Worse	Definitely Worse	N/A
Adobe Acrobat	2	2	12	0	0	2
MS Word	0	1	11	3	0	1
Ms Excel	0	2	13	0	0	1
MS PowerPoint	1	1	11	1	0	2
MS Access	0	0	7	0	0	9
MS Visio	0	1	6	0	0	9
MS Frontpage	0	0	6	0	0	10
MS Project	0	0	6	0	0	10
MS Publisher	0	0	6	0	0	10
Dreamweaver	0	0	5	0	0	11
WinZip	0	1	5	0	0	10
Internet Exp	0	2	10	1	2	1
Firefox	0	1	6	1	0	8
Quick Time	0	1	3	1	0	11
Shockwave/Flash	0	0	3	0	0	13
Real Player	0	0	4	3	0	9
WMP 10	0	1	6	5	1	3
MiniTab	0	0	3	2	0	11
MathType	0	0	1	0	0	15
Navfit 98A	0	2	3	0	0	11

Table 8. User Application Evaluation Results

Question 8 was designed for each user to assess the relevance of the experiment's applications to their everyday PC experience.

- 13 of 16 users answered "Yes" they normally use the experiment applications in their work.
- 2 of 16 users answered "No".
- 1 user did not answer this question.

4. Scenario Evaluation

Question 11 asked users to categorize a list of thin client scenarios as an advantage, disadvantage, or no opinion. Table 9 displays the results of this question.

SCENARIO	ADVANTAGE	DISADVANTAGE	NO OPINION
No CD ROM drive	0	14	2
No floppy drive	1	6	9
USB interface	14	0	2
User friendly	15	0	1
Noise reduction	14	0	2
Smaller support staff	16	0	0
Central administration	14	0	2
Central data storage	10	4	2
Power saving	15	0	1
Cost reduction	15	0	1
Increase security	14	0	2

Table 9. Thin Client Scenario Assessment Results

5. User Feedback

The purpose of question 13 was to give the users an opportunity to share their likes and dislikes about thin client technology. Question 14 was designed as a “write-in” to gather experiment user recommendations and general comments. Below is a compilation of user likes, dislikes, recommendations, and general comments.

1.) Likes

- Size, security, ease of use, minimization of administrative support burdens, and cost if they are in fact cheaper.

- Good for staterooms and work centers.
- No real opinion yet.
- Ability to get rid of desktops.
- Simplicity once logged on.
- Reduced costs, allows for more units which is good with amount of work being done on computers.
- Security is most important advantage, especially in defense environment.
- Cost benefit seems good.
- Like the noise reduction.
- Just as fast, space saving, I think this has great shipboard potential and would love to implement. You should look at this and how it could be used aboard Littoral Combat Ship (LCS).

2.) Dislikes

- Slow media files.
- Centralized data storage, how secure is my information?
- Slow internet.
- If common use files used, there is the limitation of read-only for more than one person using. But it is fine considering managers only want one person editing at a time.
- Multi-tasking seems a little slower. Running a media file while surfing the net slowed down surfing.

- Maybe security concerns with wireless connection.
- Media programs seemed to lag in performance.
- If system fails users are out of luck.
- Peripherals are a necessity; thus far a 3.5” drive and/or CD ROM drive would be a virtual necessity on any installation or command.
- Lack of a hard drive.
- Lack of redundancy, problem on server eliminates all effectiveness.
- No CD ROM or Floppy (but you can use external ones)
- Unable to get any internet, video or audio playback (may be my problem, but it did seem to be a drawback)

3.) Recommendations

- Blind test to minimize bias, everyone involved, students/faculty/staff, were from NPS with a decent understanding of computers and applications. Introduce more randomness to experiment with a more random sample of users, and multiple sessions to test for “actual variability” vice noise in the experiment.
- Perhaps run this with only one computer then compare to using the one Wyse box that you have available.
- Would like to look at Virtual Machines to give users various configurations.

4.) General Comments

- Good job.
- Experiment well laid out and executed.
- Well organized!
- Good flexibility. Left time to look at many different components of Thin Client Server used in the experiment.

B. ETHERPEEK DATA

Etherpeek was the software chosen to monitor server activities for the duration of the experiment. This software is a tool designed to give IT managers the ability to effectively monitor the efficiency of the network servers. The software was located on a laptop that was borrowed from the NPS network operations center. Etherpeek's filters were set to monitor activity to and from the experiment server. The information gathered was stored in information packets that were set to a size of one hundred megabytes. A total of eleven packets of data were gathered in one hundred minutes. Four of the packets were chosen to display statistics from four data points; logon, server only operations, one half of the group using the internet, the entire group using the internet.

1. Logon Data Results

Table 10 displays a summary of statistics gathered during the user login phase.

Start Time:	3/9/2006 12:51:58
Duration:	0:02:00

Stat	Bytes	Packets	B/sec	P/sec
Dropped Packets	-	0	-	0.000
Total Bytes	620,798,203	-	5,158,378.662	-
Total Packets	-	724,116	-	6,016.874
Total Broadcast	1,556	11	12.929	0.091
Average Utilization (percent)	41.652	41.652	41.652	41.652
Current Utilization (percent)	31.876	31.876	31.876	31.876
Max Utilization (percent)	62.513	62.513	62.513	62.513
Max Utilization (bits/s)	62,513,136.000	62,513,136.000	62,513,136.000	62,513,136.000
Average Utilization (bits/s)	41,652,109.228	41,652,109.228	41,652,109.228	41,652,109.228
Current Utilization (bits/s)	31,876,384.000	31,876,384.000	31,876,384.000	31,876,384.000
Physical Addresses Seen	19	19	19	19
IP Addresses Seen	47	47	47	47
Flows Analyzed (Total)	-	623	-	5.177
Flows Analyzed (Current)	-	623	-	5.177
Flows Analyzed (Recycled)	-	0	-	0.000
Node Pairs Analyzed (Total)	-	49	-	0.407
Node Pairs Analyzed (Current)	-	49	-	0.407
Node Pairs Analyzed (Recycled)	-	0	-	0.000
Packets Dropped	-	0	-	0.000
Busy Network or Server	-	46	-	0.382
Inefficient Client	-	2,659	-	22.094
Low Server-to-Client Throughput	-	83	-	0.690
Low Client-to-Server Throughput	-	69	-	0.573
Non-Responsive Client	-	0	-	0.000
Non-Responsive Server	-	0	-	0.000
One-Way Traffic	-	0	-	0.000
Slow Server Response Time	-	313	-	2.601

Table 10. Summary of Login Data

Figure 17 is a representation of packet size distribution during the login phase.

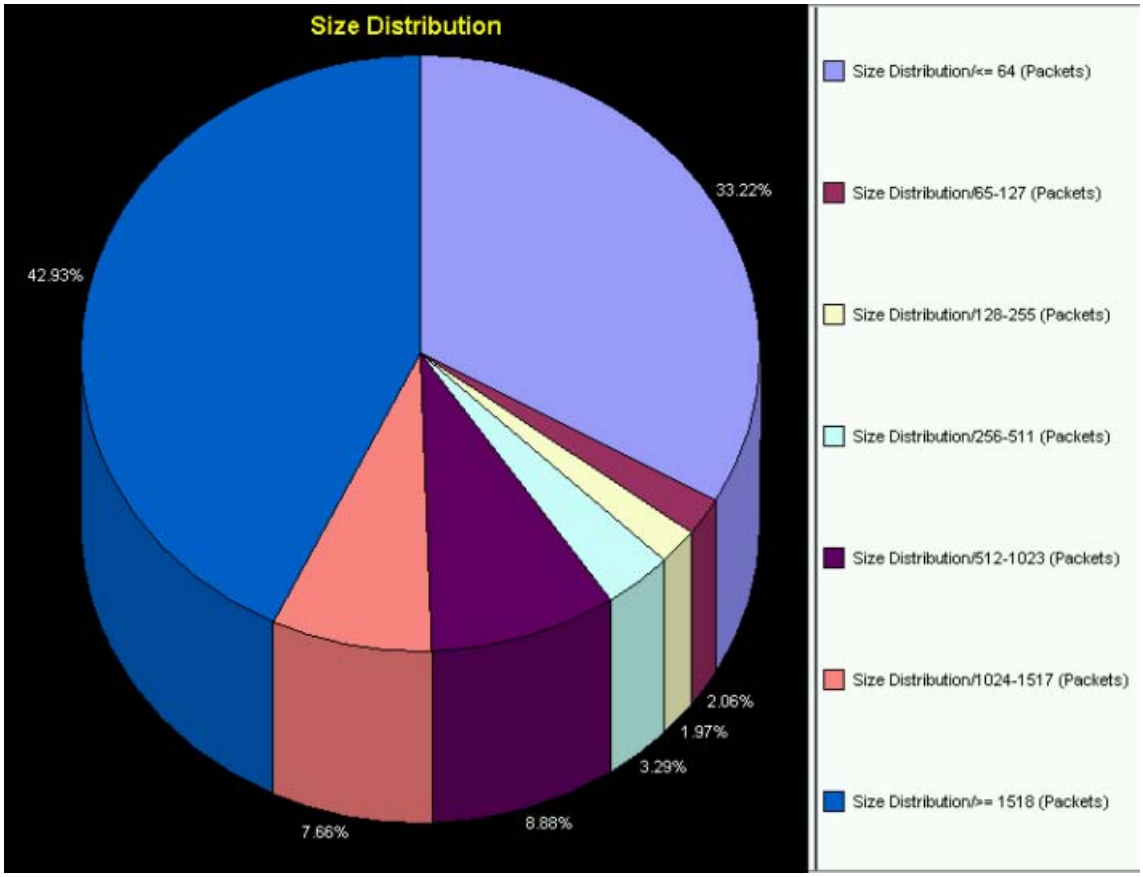

Figure 17. Login Packet Size Distribution

Table 11 shows the communication statistics between the users and the server in percentages, bytes, and packets during the login phase.

Total Packets:	724,116
Total Bytes:	620,798,203

Node		%	Bytes	Packets
IP-131.120.40.230 (SERVER)	→	97.359%	604,405,358	481,097
	←	2.641%	16,392,845	243,019
IP-131.120.40.35	→	0.350%	2,174,482	33,719
	←	14.218%	88,267,148	67,844
IP-131.120.40.31	→	0.288%	1,790,410	27,868
	←	11.627%	72,178,569	56,026
IP-131.120.42.206	→	0.268%	1,666,576	25,555
	←	10.339%	64,182,758	50,696
IP-131.120.40.228	→	0.247%	1,535,692	23,751
	←	9.774%	60,676,230	47,359
IP-131.120.40.38	→	0.246%	1,528,126	23,675
	←	9.568%	59,395,790	47,310
IP-131.120.40.249	→	0.237%	1,470,523	22,667
	←	9.340%	57,984,301	45,104
IP-131.120.40.34	→	0.228%	1,416,510	21,720
	←	8.738%	54,244,461	43,126
IP-131.120.40.237	→	0.134%	831,526	12,689
	←	5.080%	31,536,434	25,070
IP-131.120.42.212	→	0.137%	853,486	13,179
	←	4.763%	29,568,215	26,040
IP-131.120.41.114	→	0.121%	751,439	11,616
	←	4.713%	29,255,267	23,030
IP-131.120.40.235	→	0.119%	741,386	11,121
	←	4.395%	27,283,636	21,699
IP-131.120.40.179	→	0.102%	632,701	9,439
	←	3.689%	22,899,249	18,293
IP-131.120.40.14	→	0.025%	154,744	2,289
	←	0.944%	5,862,877	4,618
IP-131.120.40.77	→	0.011%	69,200	803
	←	0.085%	526,999	1,179
IP-131.120.42.218	→	0.007%	45,812	466
	←	0.020%	124,387	505
IP-131.120.42.195	→	0.007%	45,025	445
	←	0.016%	100,999	419

Table 11. Login Node Statistics

Table 12 displays the various protocols in operation during the login phase.

Total Packets:	724,116
Total Bytes:	620,798,203
Protocols:	12

Protocol	**%**	**Bytes**	**Packets**
Ethernet Type 2	0.000%	0	0
IP	0.000%	0	0
TCP	0.000%	0	0
Windows Terminal Services	98.950%	614,279,656	714,324
HTTP	0.159%	985,732	4,665
DCE	0.000%	64	1
UDP	0.807%	5,012,660	4,520
MGCP	0.081%	502,578	475
DNS	0.002%	13,373	104
NetBIOS	0.000%	0	0
Name Svc	0.000%	2,052	21
BOOTP	0.000%	2,088	6

Table 12. Login Protocol Statistics

2. Server Only Data Results

Table 13 shows the summary of statistics gathered during the experiment when the users were asked to execute programs only on the server. There were no Internet operations being executed at that time.

Start Time:	3/9/2006 12:56:01
Duration:	0:02:10

Stat	Bytes	Packets	B/sec	P/sec
Dropped Packets	-	0	-	0.000
Total Bytes	601,844,510	-	4,596,577.506	-
Total Packets	-	723,304	-	5,524.222
Total Broadcast	1,460	12	11.151	0.092
Average Utilization (percent)	37.126	37.126	37.126	37.126
Current Utilization (percent)	27.042	27.042	27.042	27.042
Max Utilization (percent)	63.555	63.555	63.555	63.555
Max Utilization (bits/s)	63,555,272.000	63,555,272.000	63,555,272.000	63,555,272.000
Average Utilization (bits/s)	37,126,170.280	37,126,170.280	37,126,170.280	37,126,170.280
Current Utilization (bits/s)	27,042,480.000	27,042,480.000	27,042,480.000	27,042,480.000
Physical Addresses Seen	19	19	19	19
IP Addresses Seen	58	58	58	58
Flows Analyzed (Total)	-	277	-	2.116
Flows Analyzed (Current)	-	277	-	2.116
Flows Analyzed (Recycled)	-	0	-	0.000
Node Pairs Analyzed (Total)	-	60	-	0.458
Node Pairs Analyzed (Current)	-	60	-	0.458
Node Pairs Analyzed (Recycled)	-	0	-	0.000
Packets Dropped	-	0	-	0.000
Busy Network or Server	-	61	-	0.466
Inefficient Client	-	9,210	-	70.341
Low Server-to-Client Throughput	-	76	-	0.580
Low Client-to-Server Throughput	-	107	-	0.817
Non-Responsive Client	-	0	-	0.000
Non-Responsive Server	-	0	-	0.000
One-Way Traffic	-	0	-	0.000
Slow Server Response Time	-	419	-	3.200

Table 13. Summary of Server Only Data

Figure 18 is a graphic representation of the packet size distribution during the server only phase.

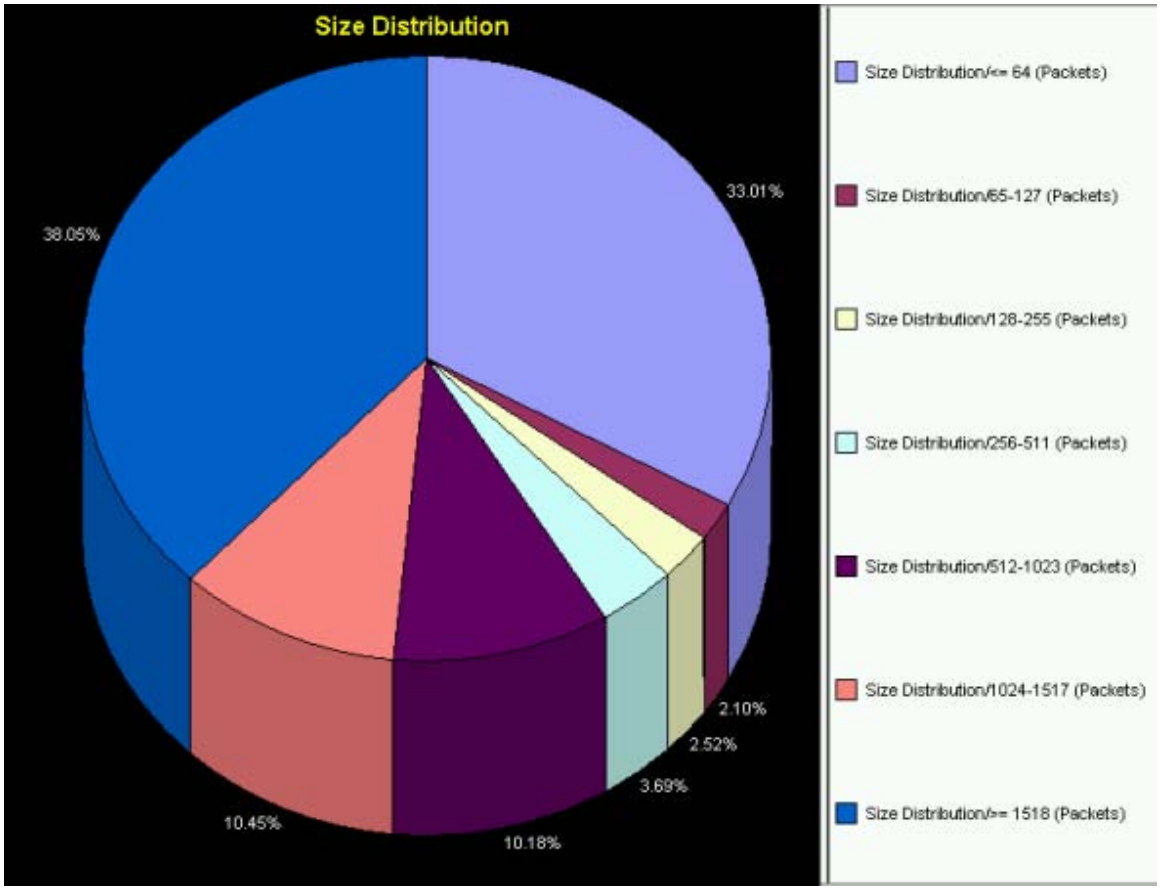

Figure 18. Server Only Packet Size Distribution

Table 14 shows the communication statistics between the users and the server in percentages, bytes, and packets during the server only phase.

Total Packets:	723,304
Total Bytes:	601,844,510

Node		%	Bytes	Packets
IP-131.120.40.230 (SERVER)	→	97.232%	585,183,424	480,439
	←	2.768%	16,661,086	242,865
IP-131.120.42.218	→	0.422%	2,539,595	39,466
	←	15.669%	94,302,102	79,746
IP-131.120.42.206	→	0.383%	2,305,284	35,688
	←	15.296%	92,058,821	71,209
IP-131.120.40.77	→	0.331%	1,994,293	30,982
	←	12.207%	73,465,104	62,318
IP-131.120.41.114	→	0.301%	1,810,417	27,983
	←	10.970%	66,022,714	55,883
IP-131.120.40.179	→	0.241%	1,447,678	22,474
	←	9.724%	58,525,330	46,178
IP-131.120.40.31	→	0.245%	1,475,140	22,769
	←	9.655%	58,105,379	45,356
IP-131.120.40.34	→	0.233%	1,400,195	21,509
	←	9.047%	54,446,461	42,126
IP-131.120.40.14	→	0.093%	556,963	8,539
	←	3.711%	22,333,454	17,200
IP-131.120.42.212	→	0.107%	642,277	9,239
	←	3.042%	18,305,617	17,466
IP-131.120.40.38	→	0.082%	496,483	7,294
	←	2.952%	17,766,641	14,032
IP-131.120.40.228	→	0.067%	400,913	6,045
	←	2.490%	14,983,648	11,894
IP-131.120.40.237	→	0.050%	301,936	4,331
	←	1.540%	9,268,710	8,153
IP-131.120.40.249	→	0.024%	144,435	1,838
	←	0.503%	3,027,952	3,078
IP-131.120.40.235	→	0.022%	129,469	1,324
	←	0.087%	525,596	1,457
IP-131.120.40.35	→	0.006%	35,309	359
	←	0.102%	611,347	639
IP-131.120.42.195	→	0.015%	92,692	918
	←	0.056%	339,300	979

Table 14. Server Only Node Statistics

Table 15 displays the various protocols in operation during the server only phase.

Total Packets:	723,304
Total Bytes:	601,844,510
Protocols:	12

Protocol	%	Bytes	Packets
Ethernet Type 2	0.000%	0	0
IP	0.000%	0	0
TCP	0.000%	0	0
Windows Terminal Services	97.766%	588,400,840	709,844
HTTP	0.153%	922,803	2,250
UDP	2.010%	12,094,763	10,706
MGCP	0.068%	411,106	388
DNS	0.002%	12,350	92
NetBIOS	0.000%	0	0
Name Svc	0.000%	2,148	22
DG Dgram	0.000%	0	0
CIFS/SMB	0.000%	500	2

Table 15. Server Only Protocol Statistics

3. Internet 1 Data Results

Internet 1 data was taken with only one-half of the users accessing the internet while the remaining volunteers continued with their server operations. Table 16 is a summary of the statistics gathered during this phase.

Start Time:	3/9/2006 13:01:45
Duration:	0:04:43

Stat	Bytes	Packets	B/sec	P/sec
Dropped Packets	-	0	-	0.000
Total Bytes	570,050,669	-	2,014,292.641	-
Total Packets	-	729,894	-	2,579.104
Total Broadcast	2,420	20	8.551	0.071
Average Utilization (percent)	16.279	16.279	16.279	16.279
Current Utilization (percent)	3.572	3.572	3.572	3.572
Max Utilization (percent)	50.146	50.146	50.146	50.146
Max Utilization (bits/s)	50,146,280.000	50,146,280.000	50,146,280.000	50,146,280.000
Average Utilization (bits/s)	16,279,403.803	16,279,403.803	16,279,403.803	16,279,403.803
Current Utilization (bits/s)	3,572,176.000	3,572,176.000	3,572,176.000	3,572,176.000
Physical Addresses Seen	19	19	19	19
IP Addresses Seen	145	145	145	145
Flows Analyzed (Total)	-	736	-	2.601
Flows Analyzed (Current)	-	736	-	2.601
Flows Analyzed (Recycled)	-	0	-	0.000
Node Pairs Analyzed (Total)	-	146	-	0.516
Node Pairs Analyzed (Current)	-	146	-	0.516
Node Pairs Analyzed (Recycled)	-	0	-	0.000
Packets Dropped	-	0	-	0.000
Busy Network or Server	-	152	-	0.537
Inefficient Client	-	4,276	-	15.109
Low Server-to-Client Throughput	-	202	-	0.714
Low Client-to-Server Throughput	-	249	-	0.880
Non-Responsive Client	-	0	-	0.000
Non-Responsive Server	-	0	-	0.000
One-Way Traffic	-	0	-	0.000
Slow Server Response Time	-	926	-	3.272

Table 16. Summary of Internet 1 Data

Figure 19 is a graphic representation of packet size distribution during the Internet 1 phase.

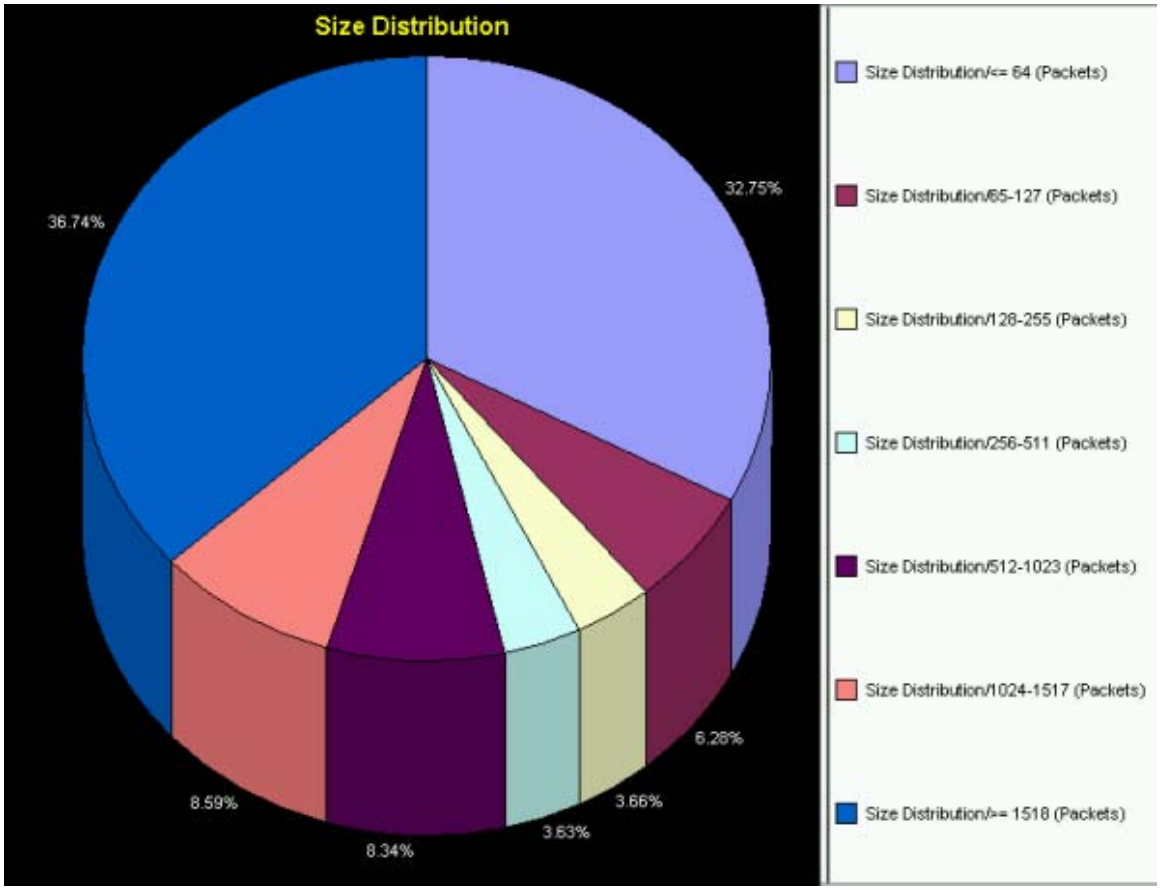

Figure 19. Internet 1 Packet Size Distribution

Table 17 shows the communication statistics between the users and the server in percentages, bytes, and packets during the Internet 1 phase.

Total Packets:	729,894
Total Bytes:	570,050,669

Node		%	Bytes	Packets
IP-131.120.40.230 (SERVER)	→	94.377%	537,994,629	472,062
	←	5.623%	32,056,040	257,832
IP-131.120.40.35	→	0.795%	4,532,338	70,332
	←	31.080%	177,169,576	141,796
IP-131.120.40.77	→	0.335%	1,907,379	29,296
	←	12.724%	72,533,507	57,357
IP-131.120.40.249	→	0.340%	1,939,789	29,529
	←	12.116%	69,067,894	57,968
IP-131.120.40.179	→	0.258%	1,467,900	22,178
	←	9.356%	53,331,105	42,961
IP-131.120.42.218	→	0.223%	1,271,956	19,169
	←	8.372%	47,725,106	37,762
IP-131.120.40.228	→	0.164%	932,094	14,275
	←	6.000%	34,201,977	28,192
IP-131.120.40.38	→	0.130%	742,076	10,949
	←	4.079%	23,253,692	20,688
IP-131.120.40.31	→	0.109%	619,863	8,778
	←	3.020%	17,217,153	16,411
IP-131.120.42.212	→	1.350%	7,693,899	17,730
	←	1.373%	7,824,804	20,204
IP-131.120.40.34	→	0.083%	473,528	6,108
	←	1.875%	10,689,450	10,765
IP-131.120.40.235	→	0.084%	477,820	5,775
	←	1.403%	7,998,238	9,063
IP-131.120.40.14	→	0.062%	356,222	4,669
	←	1.113%	6,342,499	7,517
IP-131.120.41.114	→	0.046%	263,358	3,100
	←	0.539%	3,074,511	4,396
IP-131.120.40.237	→	0.031%	177,458	2,182
	←	0.399%	2,274,717	3,170
IP-131.120.42.206	→	0.022%	123,416	1,769
	←	0.366%	2,087,949	3,120
IP-131.120.42.195	→	0.030%	173,156	1,988
	←	0.317%	1,805,713	2,612

Table 17. Internet 1 Node Statistics

Table 18 displays the various protocols in operation during the Internet 1 phase.

Total Packets:	729,894
Total Bytes:	570,050,669
Protocols:	16

Protocol	%	Bytes	Packets
Ethernet Type 2	0.000%	0	0
IP	0.000%	0	0
TCP	0.000%	0	0
Windows Terminal Services	95.902%	546,687,473	700,216
HTTP	1.365%	7,778,911	13,385
HTTPS	0.391%	2,229,775	3,810
HTTP Proxy	0.035%	199,738	221
CIFS/SMB	0.002%	10,602	61
NetBIOS	0.000%	0	0
SessMsg	0.000%	1,056	16
UDP	2.199%	12,537,916	11,097
DNS	0.013%	74,252	544
MGCP	0.092%	524,754	496
NetBIOS	0.000%	0	0
Name Svc	0.001%	4,104	42
BOOTP	0.000%	2,088	6

Table 18. Internet 1 Protocol Statistics

4. Internet 2 Data Results

Internet 2 data refers to the information gathered when all users were asked to access the Internet simultaneously. Table 19 is a summary of the data gathered during this phase of the experiment.

Start Time:	3/9/2006 13:13:23
Duration:	0:06:51

Stat	**Bytes**	**Packets**	**B/sec**	**P/sec**
Dropped Packets	-	0	-	0.000
Total Bytes	560,396,496	-	1,362,904.571	-
Total Packets	-	730,468	-	1,776.525
Total Broadcast	1,084	10	2.636	0.024
Average Utilization (percent)	11.017	11.017	11.017	11.017
Current Utilization (percent)	28.741	28.741	28.741	28.741
Max Utilization (percent)	30.671	30.671	30.671	30.671
Max Utilization (bits/s)	30,671,432.000	30,671,432.000	30,671,432.000	30,671,432.000
Average Utilization (bits/s)	11,016,934.141	11,016,934.141	11,016,934.141	11,016,934.141
Current Utilization (bits/s)	28,741,384.000	28,741,384.000	28,741,384.000	28,741,384.000
Physical Addresses Seen	19	19	19	19
IP Addresses Seen	284	284	284	284
Flows Analyzed (Total)	-	1,569	-	3.816
Flows Analyzed (Current)	-	1,569	-	3.816
Flows Analyzed (Recycled)	-	0	-	0.000
Node Pairs Analyzed (Total)	-	286	-	0.696
Node Pairs Analyzed (Current)	-	286	-	0.696
Node Pairs Analyzed (Recycled)	-	0	-	0.000
Packets Dropped	-	0	-	0.000
Busy Network or Server	-	168	-	0.409
Inefficient Client	-	6,493	-	15.791
Low Server-to-Client Throughput	-	343	-	0.834
Low Client-to-Server Throughput	-	285	-	0.693
Non-Responsive Client	-	3	-	0.007
Non-Responsive Server	-	17	-	0.041
One-Way Traffic	-	1	-	0.002
Slow Server Response Time	-	1,223	-	2.974

Table 19. Summary of Internet 2 Data

Figure 20 is a graphic representation of packet size distribution during the Internet 2 phase.

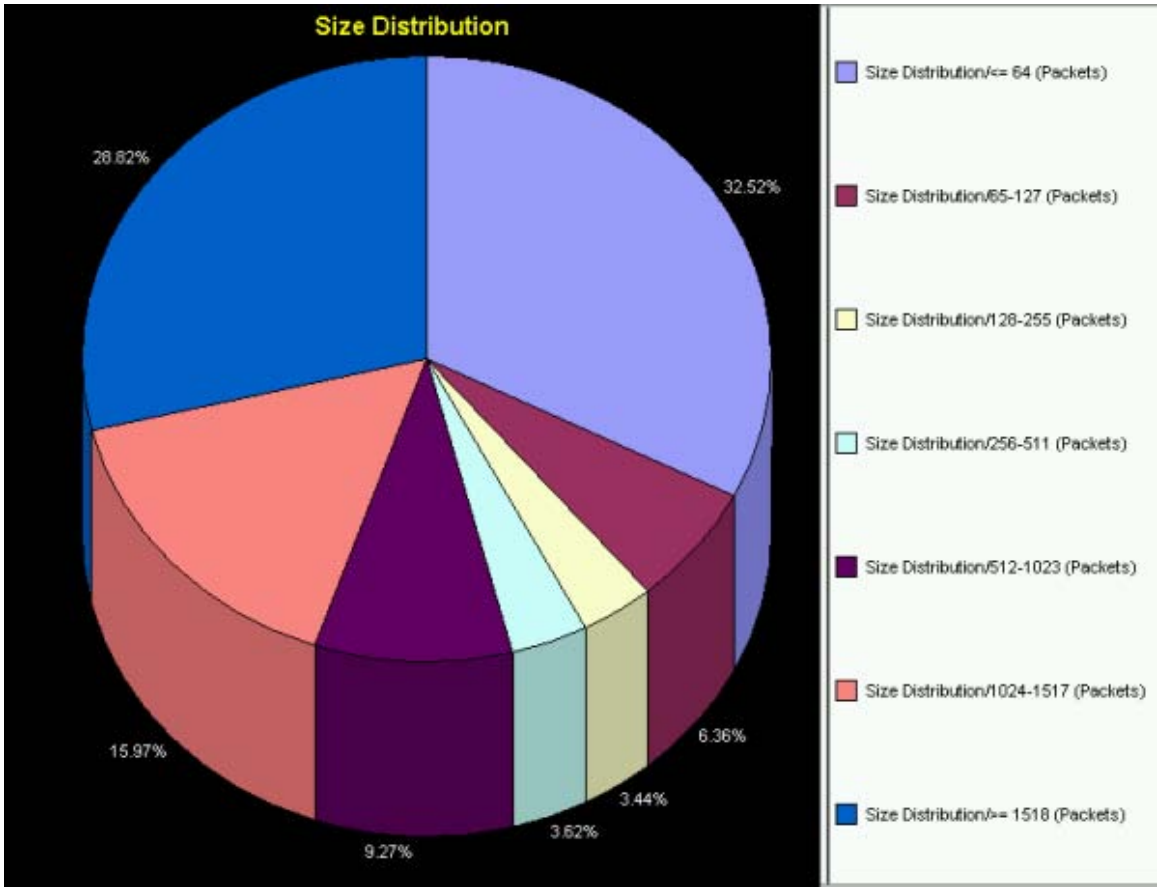

Figure 20. Internet 2 Packet Size Distribution

Table 20 shows the communication statistics between the users and the server in percentages, bytes, and packets during the Internet 2 phase.

Total Packets:	730,468
Total Bytes:	560,396,496

Node		%	Bytes	Packets
IP-131.120.40.230 (SERVER)	→	87.675%	491,329,094	457,851
	←	12.325%	69,067,402	272,617
IP-131.120.40.235	→	1.225%	6,863,663	105,920
	←	46.199%	258,895,021	210,471
IP-131.120.40.34	→	0.318%	1,783,876	26,185
	←	11.178%	62,642,727	50,360
IP-131.120.41.114	→	0.287%	1,610,015	24,236
	←	10.168%	56,979,432	47,555
IP-131.120.40.77	→	0.208%	1,167,805	17,502
	←	7.462%	41,814,880	34,582
IP-131.120.40.38	→	0.088%	493,650	6,972
	←	2.210%	12,385,775	12,539
IP-131.120.40.35	→	0.057%	319,027	4,377
	←	2.065%	11,574,271	10,372
IP-131.120.40.31	→	0.075%	419,414	5,756
	←	1.936%	10,850,259	10,892
IP-131.120.42.206	→	0.076%	426,424	5,077
	←	1.024%	5,736,620	7,558
IP-131.120.40.228	→	0.044%	247,570	3,378
	←	0.888%	4,975,911	5,802
IP-131.120.40.14	→	0.054%	301,932	3,711
	←	0.850%	4,765,946	5,597
IP-131.120.42.218	→	0.064%	360,661	4,441
	←	0.772%	4,325,064	6,792
IP-131.120.40.249	→	0.040%	222,568	2,997
	←	0.674%	3,778,872	4,934
IP-131.120.40.179	→	0.071%	396,329	4,320
	←	0.544%	3,049,296	5,564
IP-131.120.42.195	→	0.045%	249,382	2,732
	←	0.378%	2,115,660	3,446
IP-131.120.40.237	→	0.049%	274,364	3,182
	←	0.341%	1,909,911	3,992
IP-131.120.42.212	→	0.099%	552,482	4,579
	←	0.179%	1,001,832	4,344

Table 20. Internet 2 Node Statistics

Table 21 displays the various protocols in operation during the Internet 2 phase.

Total Packets:	730,468
Total Bytes:	560,396,496
Protocols:	31

Protocol	%	Bytes	Packets
Ethernet Type 2	0.000%	0	0
IP	0.000%	0	0
TCP	0.000%	0	0
Windows Terminal Services	86.641%	485,530,368	640,766
HTTP	3.813%	21,365,794	35,611
RTSP	6.205%	34,773,463	35,455
HTTPS	0.206%	1,156,212	2,239
HTTP Proxy	0.011%	63,112	81
SessMsg	0.000%	1,176	18
Xact2 Function, Byte In/Out	0.000%	765	6
Sess Set Up And X	0.000%	1,460	4
User Logoff & X	0.000%	202	2
Tree Disconn	0.000%	194	2
Tree Conn & X	0.000%	260	2
Negotiate Protocol	0.000%	438	2
Sess Req	0.000%	260	2
Pos Sess Rsp	0.000%	128	2
CIFS/SMB	0.001%	6,831	36
DCE	0.002%	11,504	8
UDP	3.099%	17,367,483	15,506
DNS	0.017%	96,638	680
NetBIOS	0.000%	0	0
Name Svc	0.000%	2,256	23
CIFS/SMB	0.000%	220	1
MGCP	0.003%	17,420	18
ICMP	0.000%	0	0
Echo Req	0.000%	156	2
Echo Reply	0.000%	156	2

Table 21. Internet 2 Protocol Statistics

5. Etherpeek Data Conclusions

The tables and figures presented a sample view of the information provided in the Etherpeek packets. The data in the diagrams showed expected trends.

From the summary of data tables it is important to note that during the entire one hundred minutes of the experiment there was not one single packet dropped. The server also showed strong performance with less than .1% of the total packets transferred reaching the clients inefficiently. Lastly, the summary table shows that during the experiment the highest utilization of server capacity was 63.55%; this occurred during the server only phase. This indicates that the server used is capable of handling sixteen users with some room for expansion.

The packet size distribution graphs showed expected results. The smallest and largest packets constituted the top two portions in every phase of the experiment. This was expected because client keystroke commands to the server are transferred in small packets. The data sent back to the client is sent in the most efficient manner which in most cases will be the largest packet. During the Internet phase of the experiment the graphs showed an increased distribution to the other packet sizes. This pattern was likely created by the additional protocols in operation during the Internet phase.

The node statistics were arranged by order of which Internet Protocol (IP) number transferred the largest percentage of bytes and packets into the network. As expected the server always transferred the largest percentage of data.

The protocol statistics showed that during the entire experiment Windows Terminal Services was the dominant protocol. This was expected because of the server's use of RDP to communicate with the clients. It also showed that during the Internet phase there were additional protocols in operation demonstrating the server's ability to handle multiple protocols efficiently.

C. CONCLUSIONS

The literature that was reviewed as part of the background research for this thesis supports that thin client technology, once almost obsolete, is emerging on the forefront of technology as the promising future of computer networking.

TCSBC has several advantages such as lower TCO, increased IT staff efficiency, and extremely energy efficient. There are also several concerns such as expensive, robust servers, dependency on the server, and user resistance to new technology. The increasing popularity of TCSBC indicates that the advantages are outweighing the concerns.

For this thesis research experiment, TCSBC was clearly defined as a desktop appliance that does not contain any moving component such as a hard drive, floppy drive, or CD-ROM, and executes applications from a central server instead of a traditional desktop PC.

A brief description of the four most common thin client types and their common network applications was discussed. This was important for this project as networks are so specialized that the most vital part in their

operation is matching the proper technology with the appropriate job.

The main purpose of this thesis was to examine a sample of options that may be compatible with a naval command's network operations. Three options were examined; Expanion L100, Wyse V90, and a laptop. The specifications, benefits, and problems with each option were discussed. The Expanion system worked well; however its incompatibility with Windows' updates was a major factor in its disqualification. The laptop did not relieve the IT staff of the maintenance requirement which is a large benefit of a true thin client. In the end, the Wyse V90 did the best overall job of meeting the selection criteria with its reasonable costs, easy setup, excellent operation with Windows, and no maintenance requirements.

The only way to know for certain that the Wyse V90 could be an option at a naval command was to test it in a multi-user environment. An experiment was designed to allow users to assess application performance and share their objective opinion. The compilation of the experiment results indicates that it was a success in both application performance and user opinion.

In conclusion, there is strong evidence in this research to suggest that TCSBC has the potential to be successfully implemented at any naval command.

D. SUGGESTIONS FOR FURTHER RESEARCH

Due to funding and time constraints there was only one Wyse V90 terminal available for testing. Consideration should be given to finding a Navy sponsor to purchase multiple Wyse systems or an equivalent product and repeat

the experiment again in a controlled lab environment. Additionally, if that test proves successful, a full implementation and test needs to be conducted at a naval command willing to oblige an operational test.

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APPENDIX A. IRB PACKAGE

Dr. Douglas E. Brinkley
Graduate School of Business and Public Policy
Naval Postgraduate School
Monterey, California 93943

831-656-2771
DSN: 756-2771
Fax: 831-656-2771
brinkley@nps.edu

Date: 3 March 2006

To: Protection of Human Subjects Committee

Subject: Application for Human Subjects Review: Thin Client Usability Study

1. Attached is a set of documents outlining research for the usability of thin client computers within the NPS academic environment and other US Navy organizations.

2. We are requesting approval to administer the described anonymous user satisfaction survey to faculty and students.

3. A copy of the participant consent form and anonymous survey is attached.

4. We understand that any modifications to the protocol or instruments/measures will require submission of updated IRB paperwork and possible re-review. Similarly, we understand that any untoward event that involves a research participant will be reported immediately to the IRB Chair and NPS Dean of Research.

Douglas E. Brinkley

APPLICATION FOR HUMAN SUBJECTS REVIEW (HSR)	HSR NUMBER *(to be assigned)*
PRINCIPAL INVESTIGATOR(S) *(Full Name, Code, Telephone)* DOUGLAS E. BRINKLEY, GB/BI, 831-656-2771	
APPROVAL REQUESTED [X] New [ ] Renewal	
LEVEL OF RISK [X] Exempt [ ] Minimal [ ] More than Minimal Justification: Participation is voluntary and results will be anonymous. Persons in government or contractor positions are at no known risk.	
WORK WILL BE DONE IN (Site/Bldg/Rm) NPS, Ingersoll Hall, Room 224	ESTIMATED NUMBER OF DAYS TO COMPLETE 180 days
MAXIMUM NUMBER OF SUBJECTS 50	ESTIMATED LENGTH OF EACH SUBJECT'S PARTICIPATION: 2 hrs
SPECIAL POPULATIONS THAT WILL BE USED AS SUBJECTS [ ] Subordinates [ ] Minors [X] NPS Students [ ] Special Needs (e.g. Pregnant women) Specify safeguards to avoid undue influence and protect subject's rights: Participation is voluntary and results will be anonymous.	
OUTSIDE COOPERATING INVESTIGATORS AND AGENCIES N/A [ ] A copy of the cooperating institution's HSR decision is attached.	
DESCRIPTION OF RESEARCH (attach additional sheet if needed). The purpose of this thesis is to examine Thin Client/Server architecture, focusing on the area of compatibility with IT21 prescribed software and performance compared with stand-alone computers presently in use. To facilitate the study a prototype Thin Client network will be established at NPS in Ingersoll Hall, computer lab room 224. NPS students and faculty will be asked to test various software applications and fill out a survey giving their opinions of the system.	
I have read and understand NPS Notice on the Protection of Human Subjects. If there are any changes in any of the above information or any changes to the attached Protocol, Consent Form, or Debriefing Statement, I will suspend the interviews until I obtain new Committee approval. SIGNATURE_____ DATE_____	

Naval Postgraduate School
Participant Consent Form &
Minimal Risk Statement

Introduction. You are invited to participate in a study entitled Thin Client Usability Assessment being conducted by the Naval Postgraduate School as a part of a thesis project.

Procedures. If I agree to participate in this study, I understand I will be provided with an explanation of the purposes of the research, a description of the procedures to be used, identification of any experimental procedures, and the expected duration of my participation. *Synopsis*: A group of students, faculty, and staff will meet in a NPS computer lab with network connection to an application server in Ingersoll Hall 380. Participants will use their computers to run applications on the application server via the Remote Desktop Protocol (RDP). This mode of operation will simulate the use of thin client terminals. Participants will complete a questionnaire giving their assessment of the thin client architecture and its compatibility for use here at NPS.

Risks and Benefits. I understand that this project does not involve greater than minimal risk and involves no known reasonably foreseeable risks or hazards greater than those encountered in everyday life. I have also been informed of any benefits to myself or to others that may reasonably be expected as a result of this research.

Compensation. I understand that no tangible reward will be given. I understand that a copy of the research results will be available at the conclusion of the experiment.

Confidentiality & Privacy Act. I understand that all records of this study will be kept confidential and that my privacy will be safeguarded. No information will be publicly accessible which could identify me as a participant, and I will be identified only as a code number on all research forms. I understand that records of my participation will be maintained by NPS for five years, after which they will be destroyed.

Voluntary Nature of the Study. I understand that my participation is strictly voluntary, and if I agree to participate, I am free to withdraw at any time without prejudice.

Points of Contact. I understand that if I have any questions or comments regarding this project upon the completion of my participation, I should contact the Principal Investigator, Dr. Douglas E. Brinkley, 656-2771, brinkley@nps.edu. Any medical questions should be addressed to LTC Eric Morgan, MC, USA, (CO, POM Medical Clinic), (831) 242-7550, eric.morgan@nw.amedd.army.mil.

Statement of Consent. I have read and understand the above information. I have asked all questions and have had my questions answered. I agree to participate in this study. I will be provided with a copy of this form for my records.

_____ _____

Participant's Signature Date

_____ _____

Researcher's Signature Date

Thin Client User Assessment Survey

User Category: Date: _____

Student ☐

Faculty ☐

Staff ☐

Introduction: Thank you for participating in this thesis research study of thin client server based computing using Remote Desktop Protocol (RDP). Your feedback is a critical factor in helping us to determine whether or not thin client computing is compatible with our academic mission here at the Naval Postgraduate School.
Your participation is strictly voluntary and these results will be kept anonymous.

---

1. If you are military, what is your branch of service? If you are faculty or staff, please skip to Question 4.

- ☐ U.S. Navy
- ☐ U.S. Marine Corps
- ☐ U.S. Army
- ☐ U.S. Air Force
- ☐ Other, please specify country and branch:

2. What is your warfare area (i.e. SWO, SC, IP, Infantry, Special forces)

3. What is your curriculum?

4. If you are faculty or staff at NPS what department are you in?

5. How complicated was the log-in procedure compared with a normal PC?

- ☐ Much more complicated
- ☐ More complicated
- ☐ Equal

☐ Easier

☐ Much easier

6. The following is a list of applications tested during the evaluation session. In comparison to what you are accustomed to on your desktop system, how would you rate the application's performance using the thin client architecture?

	Definitely Better	Better	Equal	Worse	Definitely Worse	Not Applicable
Adobe Acrobat	☐	☐	☐	☐	☐	☐
Microsoft Word	☐	☐	☐	☐	☐	☐
Microsoft Excel	☐	☐	☐	☐	☐	☐
Microsoft PowerPoint	☐	☐	☐	☐	☐	☐
Microsoft Access	☐	☐	☐	☐	☐	☐
Microsoft Visio	☐	☐	☐	☐	☐	☐
Microsoft Frontpage	☐	☐	☐	☐	☐	☐
Microsoft Project	☐	☐	☐	☐	☐	☐
Microsoft Publisher	☐	☐	☐	☐	☐	☐
Macromedia Dreamweaver	☐	☐	☐	☐	☐	☐
WinZip	☐	☐	☐	☐	☐	☐
Internet Explorer	☐	☐	☐	☐	☐	☐
Mozilla Firefox	☐	☐	☐	☐	☐	☐
Quick Time	☐	☐	☐	☐	☐	☐
Shockwave/Flash	☐	☐	☐	☐	☐	☐
Real Player	☐	☐	☐	☐	☐	☐
Windows Media Player	☐	☐	☐	☐	☐	☐
MiniTab	☐	☐	☐	☐	☐	☐
MathType	☐	☐	☐	☐	☐	☐

7. How much experience have you had using thin client computers in the past?

☐ Significant experience

☐ Some experience

- ☐ Once or twice
- ☐ Only knew they existed
- ☐ This is the first I have heard of them

8. Were all of the applications you normally use in your work included in this evaluation?

- ☐ Yes
- ☐ No

If no, please list the applications missing from your normal workstation:

9. Did you find the thin client desktop to be difficult or confusing?

- ☐ Yes
- ☐ No

10. In your opinion, is it reasonable to use thin clients in the classroom vice standalone PCs?

- ☐ Yes
- ☐ No

If no, why not?

11. How would you categorize the following thin client scenarios?

	ADVANTAGE	DISADVANTAGE	NO OPINION
No CD ROM drive	☐	☐	☐
No floppy drive	☐	☐	☐
USB interface	☐	☐	☐
User friendly	☐	☐	☐
Noise reduction	☐	☐	☐
Smaller support staff	☐	☐	☐
Central administration	☐	☐	☐

Central data storage	☐	☐	☐
Power saving	☐	☐	☐
Cost reduction	☐	☐	☐
Increase security	☐	☐	☐

12. How likely are you to recommend thin clients vice standalone PCs in your work environment?

- ☐ Definitely Will Recommend
- ☐ Probably Will Recommend
- ☐ Not Sure
- ☐ Probably Will Not Recommend
- ☐ Definitely Will Not Recommend

13. What are some things that can be done better to make this computing platform more useful to you? In other words, what were some of your likes and dislikes about the thin client architecture?

Likes:

Dislikes:

14. Were the objectives and instructions given for the experiment clearly understood? Yes / No

Do you have any suggestions for improving the experiment in the future? Constructive feedback is welcomed and appreciated.

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APPENDIX B. EXPERIMENT SURVEY / QUESTIONNAIRE

User Assessment Survey

User Category: Date: _____

Student ☐ IP Address: _____

Faculty ☐

Staff ☐

Introduction: Thank you for participating in this thesis research study of thin client server based computing using Remote Desktop Protocol (RDP). Your feedback is a critical factor in helping us to determine whether or not thin client computing is compatible with our academic mission here at the Naval Postgraduate School.
Your participation is strictly voluntary and these results will be kept anonymous.

---

1. If you are military, what is your branch of service? If you are faculty please skip to Question 4.

- ☐ U.S. Navy
- ☐ U.S. Marine Corps
- ☐ U.S. Army
- ☐ U.S. Air Force
- ☐ Other, please specify country and branch:

2. What is your warfare area (i.e. SWO, SC, IP, Infantry, Special forces)

3. What is your curriculum?

4. If you are faculty or staff at NPS what department are you in?

5. How complicated was the log-in procedure compared with a normal PC?

- ☐ Much more complicated
- ☐ More complicated
- ☐ Equal
- ☐ Easier
- ☐ Much easier

6. The following is a list of applications provided during the evaluation session. In comparison to what you are accustomed to on your desktop system, how would you rate the application's performance using the Thin Client?

	Definitely Better	Better	Equal	Worse	Definitely Worse	Not Applicable
Adobe Acrobat	☐	☐	☐	☐	☐	☐
Microsoft Word	☐	☐	☐	☐	☐	☐
Microsoft Excel	☐	☐	☐	☐	☐	☐
Microsoft PowerPoint	☐	☐	☐	☐	☐	☐
Microsoft Access	☐	☐	☐	☐	☐	☐
Microsoft Visio	☐	☐	☐	☐	☐	☐
Microsoft Frontpage	☐	☐	☐	☐	☐	☐
Microsoft Project	☐	☐	☐	☐	☐	☐
Microsoft Publisher	☐	☐	☐	☐	☐	☐
Macromedia Dreamweaver	☐	☐	☐	☐	☐	☐
WinZip	☐	☐	☐	☐	☐	☐
Internet Explorer	☐	☐	☐	☐	☐	☐
Mozilla Firefox	☐	☐	☐	☐	☐	☐
Quick Time	☐	☐	☐	☐	☐	☐
Shockwave/Flash	☐	☐	☐	☐	☐	☐
Real Player	☐	☐	☐	☐	☐	☐
Windows Media Player	☐	☐	☐	☐	☐	☐
MiniTab	☐	☐	☐	☐	☐	☐
MathType	☐	☐	☐	☐	☐	☐

7. How much experience have you had using thin client computers in the past?

- ☐ Significant experience
- ☐ Some experience
- ☐ Once or twice
- ☐ Only knew they existed
- ☐ This is the first I have heard of them

8. Were all of the applications you normally use in your work included in this evaluation?

- ☐ Yes
- ☐ No

If no, please list the applications missing from your normal workstation:

9. Did you find the thin client desktop to be difficult or confusing?

- ☐ Yes
- ☐ No

10. In your opinion, is it reasonable to use thin clients in the classroom vice standalone PCs?

- ☐ Yes
- ☐ No

If no, why not?

11. How would you categorize the following thin client scenarios?

	ADVANTAGE	DISADVANTAGE	NO OPINION
No CD ROM drive	☐	☐	☐
No floppy drive	☐	☐	☐
USB interface	☐	☐	☐
User friendly	☐	☐	☐
Noise reduction	☐	☐	☐
Smaller support staff	☐	☐	☐
Central administration	☐	☐	☐
Central data storage	☐	☐	☐
Power saving	☐	☐	☐
Cost reduction	☐	☐	☐
Increased security	☐	☐	☐

12. How likely are you to recommend thin clients vice standalone PCs in your work environment?

- ☐ Definitely Will Recommend
- ☐ Probably Will Recommend
- ☐ Not Sure
- ☐ Probably Will Not Recommend
- ☐ Definitely Will Not Recommend

13. What are some things that can be done better to make this computing platform more useful to you? In other words, what were some of your likes and dislikes about the thin client architecture?

Likes:

Dislikes:

14. Were the objectives and instructions given for the experiment clearly understood?

Yes/No

Do you have any suggestions for improving the experiment in the future? Constructive feedback is welcomed and appreciated.

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BIBLIOGRAPHY

Cole, Bernard C. 1999. *The Emergence of Net-Centric Computing.* Upper Saddle River, New Jersey: Pearson Prentice Hall.

Edwards, Jeri. 1999. *3-Tier Client/Server at Work.* Revised Ed. Hoboken, New Jersey: John Wiley & Sons, Inc.

Minasi, Mark. 2003. *Mastering Windows Server 2003.* San Francisco, California: Sybex, Inc.

Holme, Dan and Thomas, Orin. 2004. *Managing and Maintaining a Microsoft Windows Server 2003 Environment.* Redmond, Washington: Microsoft Press.

Nieh, Jason, Yang, S. Jae, and Novik, Naomi. “A Comparison of Thin-Client Computing Architectures.” November 2000. Available at URL: http://www.ncl.cs.columbia.edu/publications/cucs-022-00.pdf. Accessed 30 March 2006.[16 pages.]

Kanter, Joel. “Understanding Thin-Client/Server Computing.” 1997. Available at URL: http://members.tripod.com/~peacecraft/infomining/thinclnt.pdf. Accessed 30 March 2006. [12 pages.]

David, Barrie. “Thin Client Benefits.” March 2002. Available at URL: http://www.wyse.com/resources/whitepapers/newburn.pdf. Accessed 30 March 2006. [19 pages.]

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